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ORIGINAL ARTICLES

DISTRIBUTION OF CLAY MINERALS IN SOME TYPICAL SOIL PROFILES AT DELHI AND KARNAL

By B. B. Roy and B. B. Rudra, Indian Agricultural Research Institute, New Delhi

(Received for publication on 16 November 1951)

(With four text-figures)

FOR purposes of soil classification and soil systematisation a knowledge of the nature and properties of the clay fraction of the soil, freed from bases, that is, of the hydrogen clay is essential. X-ray and thermal analytical studies by various workers have established that the principal clay minerals found in soils belong to the groups kaolinite, montmorillonite, hydrous mica such as illite and the less common attapulgite. The clay fraction of the soil is a mixture of one or other of these principal secondary clay minerals, and the physical and chemical character of the soil and to a large degree the soil behaviour are determined by the nature and content of these clay minerals and their electrochemical properties. These properties provide the scientific basis for the understanding of such important properties of soils as base exchange, conditions of flocculation and deflocculation, permeability of soil to air and water, soil structure, shrinkage and swelling and many other aspects of soil behaviour.

A knowledge of the nature of the clay mineral not only in the surface soil, but also throughout the profile is, however, essential for gaining complete information on the development and genesis of the soil. In the present investigation such information of two soils, one from Delhi and the other from Karnal in the Punjab (India), was sought by a study of the electrochemical and other properties of hydrogen clays prepared from soil samples from different horizons of the two profiles.

Description of the soils

Delhi soil. Delhi soil, under examination, occurs within the Jumna alluvium region, the site of the profile being on a gently sloping land from the ridge to the east and north east. Mineralogical analysis of the coarse and fine sand fractions, however, indicates the soil to be aeolian in origin. Mechanical transportation of the finer material taking place through the porous top layer during the monsoon rain has resulted in a compact layer of clay at a depth of 9 inches extending upto 50 inches [Tamhane and Bhattacharjee, 1949]. Average annual rainfall is 25 inches, most of the precipitation falling during the monsoon period June to September. The winter rainfall amounts to only 2·3 inches on the average.

Profile

Site—National Physical Laboratory compound, New Delhi.

Topography—Rolling from south to north west.

Vegetation—Grass and weeds thinly dispersed, uncultivated.

Geology—Probably derived from the washings.

Location—About 75 yards S. E. of the New Delhi gate of Indian Agricultural Research Institute inside the Laboratory compound and to the north of the foundation stone.

0—7 in.—Brown sandy loam, single grain structure, loose, dry. Fresh grass at the surface and penetration of roots. No effervescence with HCl.

7—13 in.—Reddish brown sandy loam, single grain, compact, dry, roots present. No effervescence with HCl.

13—19 in.—Reddish brown, clayey, hard, compact, granular structure, dry small rootlets present, cracks are observed. No effervescence with HCl.

19—25 in.—Greyish brown, clayey, hard andcompact, granular structure, small rootlets present along the crack, small black rust spots and black concretions are seen. Slight effervescence with HCl towards the bottom.

25—31 in.—Colour darker than above, clayey, compact, granular structure, cracks present, rootlets present. Effervescence with HCl. Earth worms found along cracks and in small holes. Very small granules of ' Kankar ' are found and also brown mottling.

31—43 in.—Colour still darker, clayey, very compact and hard. Both fresh and dry rootlets present.

43—55 in.—Colour lighter than above, dark brown, not as hard as above, dry roots present, small crystals of $CaCO_3$.

55—67 in.—Brown clayey loam, granular structure, accumulation of salts, roots present, small crystals of *kankar* are seen. Effervescence with HCl.

67—91 in.—Colour lighter than above, not very hard, friable, roots less frequent. Zone of *kankar* formation.

The clay fraction is 18 per cent in the surface soil and 25 per cent in the sub-soil. Organic carbon is low and decreases down the profile from 0·29 to 0·11 per cent. The soil reaction varies between *p*H 7·5 and 7·9.

Six samples from the respective horizons 0-7 in., 7-13 in., 13-19 in., 31-43 in., 55-67 in. and 67-91 in. were selected for the present investigation.

Karnal soil. The soil falls under the Indo-Gangetic alluvium belt of the East Punjab. It was formerly under forest cover but during the past century has been intensively cultivated and irrigated by the Jumna canal. The soil is old alluvium, locally known as *bhangar.* Average annual rainfall is 30 inches, 80 per cent of which falls during the period from July to September.

Profile

Site—Block No. IV, Pit No. 6, Indian Agricultural Research Institute Sub-station, Karnal. Vegetation—Cultivated.

0-4 in.—Grey brown silt loam, cloddy. No effervescence with HCl.

4-26 in.—Grey brown silt loam, no structure, a few roots, compact. No effervescence with HCl.

26-48 in.—As above. Plenty of brown semihard, round concretions 2 to 5 mm. in size.

48-63 in.—Yellowish brown, lighter in structure, a few iron concretions, very few roots. No effervescence with HCl.

63-80 in.—Colour and texture as above, no effervescence with HCl and no concretions.

Surface soil reaction is practically neutral (pH 6·5 to 7·1) changing to mild alkalinity with depth (pH 7·2 to 8·0). Soluble salt is only 0·04—0·08 per cent.

Separation of the clay fractions

The clay fractions (<2 microns) were separated from horizon samples by dispersion in distilled water and siphoning off the top 20 cm. of the suspension after 24 hours. The organic matter was removed from the clay fraction by exhaustive treatment with 6 per cent hydrogen peroxide. All exchangeable bases were then replaced by hydrogen ions by repeated leaching with 0·02 NHCl. The hydrogen clay thus obtained was washed free of excess acid and dispersed in distilled water to obtain an approximately one per cent clay in the suspension.

Results

Delhi profile

Chemical composition of the hydrogen clays. The results of fusion analysis of the hydrogen clays from different horizons of the Delhi profile are given below :

TABLE I

Chemical composition of H-clays (per cent ignited basis)

Horizon in inches	SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{A_2O_3}$
0—7	53·87	27·46	14·97	traces	0·20	6·55	2·43	3·34
7—13	52·36	27·55	14·82	,,	0·82	5·66	2·41	3·23
13—19	53·22	29·92	14·42	,,	0·64	4·56	2·32	3·03
31—43	54·99	28·19	14·23	,,	0·67	3·75	2·54	3·32
55—67	55·11	28·59	12·33	,,	0·70	3·66	2·57	3·23
67—91	55·91	25·31	12·13	,,	1·13	3·28	2·87	3·75

Silica-sesquioxide and silica-alumina ratios of the clays do not change abruptly with depth, but vary respectively within the ranges 2·4 to 2·8 and 3·2 to 3·7. These values as also the presence of appreciable amount of non-exchangeable magnesium suggest that the clay mineral belongs to the montmorillonite-illite group. The high content of non-exchangeable potassium in the clays ranging between 6·55 per cent K_2O in the first horizon and 3·28 per cent in the lowest horizon shows, however, that illite is a major constituent of these clays. The proportion of this mineral is estimated to be about 80 per cent in the top horizon and 40 per cent in the lowest horizon, calculated on the assumption that illite has essentially the same structure as montmorillonite, with the exception that about 15 per cent of the Si^{++++} position has been replaced by Al^{+++} and the resulting negative charge is balanced by K^{+} [Grim, 1942].

Electrochemical properties

Potentiometric titration of hydrogen clays with bases NaOH and $Ba(OH)_2$ were carried out according to the method of Mukherjee [Mukherjee *et al.*, 1936; Mitra, 1942] for information on the exchange capacities and hence on the nature of the minerals contained in them. In all cases the caustic soda titration curves attribute a weak monobasic acid character to these clays, the inflexion point occurring between *p*H 7·9 and 8·5. With $Ba(OH)_2$, however, a strong monobasic acid character is indicated, the inflexion point in this case occurring between *p*H 7·1 and 7·7. These curves have thus the same form as those of pure montmorillonite-illite minerals [Mukherjee and Mitra, 1944, 1946].

The base exchange capacities of the clays, as calculated from the titration curves at *p*H 7·0 and also at inflexion points are recorded in Table II.

TABLE II

Base exchange capacity m.e. per 100 gm. clay

Horizon in inches	Titrated with NaOH		Titrated with $Ba(OH)_2$	
	At *p*H 7	At inflexion	At *p*H 7	At inflexion
0—7	26·0	39·0 (7·95)*	33·0	33·5 (7·15)
7—13	13·5	32·5 (8·65)	32·5	36·5 (7·50)
13—19	22·5	38·2 (8·50)	31·7	36·0 (7·65)
31—43	26·5	39·5 (8·30)	36·0	39·5 (7·40)
55—67	24·0	43·0 (8·55)	37·4	38·5 (7·15)
67—91	20·7	38·0 (8·30)	39·0	43·5 (7·75)

*Figures in brackets indicate *p*H at inflexion points

In the above results the base exchange capacity calculated at pH 7 on titration with $Ba(OH)_2$ has always a higher value than when titrated with NaOH, showing a regular cationic effect [Mitra, 1942]. At inflexion points, however, it is the reverse in most cases, the pH effect overshadowing the cationic effect.

The base exchange capacities of the hydrogen clays do not vary in a regular manner, but still there appears to be a tendency for these values to increase with depth. This is not very clear from the results of titration with NaOH, but with $Ba(OH)_2$, disregarding either the fourth or the fifth horizon the base exchange capacity increases regularly from 33·5 m.e. per 100 gm. clay in the first horizon to 43·5 m.e. per 100 gm. in the lowest horizon. This generally supports the conclusion arrived at from the chemical composition of the H-clays, that illite is present predominantly in the upper horizon of the profile, while montmorillonite is the dominant clay mineral in the lower horizon.

Electroviscous studies

Mukherjee and Mitra [1944] have shown that differentiation between clay minerals is possible from a study of the change in viscosity of hydrogen clay suspension in water with increasing addition of NaOH. With H-montmorillonite the viscosity at first increases, passes through a maximum value corresponding to about 60 to 80 per cent neutralisation of the clay acid by the base and then decreases. With H-kaolinite, apart from a slight initial decrease the alkali has no effect on the viscosity within the range of pH 4 to 11. In case of H-illite also there is no appreciable change in viscosity with progressive base saturation.

Application of this method to the clays under investigation showed that the viscosity of the H-clay suspension from the first horizon changed inappreciably with addition of NaOH. From the second horizon downwards the viscosity-alkali concentration curves show a maximum, the maximum rise in viscosity gradually increasing with depth, being very prominent in the lowest horizon. The percentage of neutralisation of the H-clays at the point where the viscosity is maximum varies from 61·5 to 78·3. The results are given in Table III. Fig. 1 also illustrates the change in viscosity of the H-clays from the second, fourth and the sixth horizons, with increasing base saturation.

TABLE III

Variation of viscosity with increasing base saturation

Horizon in inches	Initial viscosity in centipoise	Maximum Viscosity in centipoise	Increase in viscosity	m.e. base per 100 gm. at max. viscosity	p.c. neutralisation at max. viscosity
0—7	1·691	—	—	—	—
7—13	1·035	1·052	0·017	20	61·5
13—19	1·044	1·060	0·016	30	78·3
31—43	1·096	1·125	0·129	25	63·5
55—67	0·983	1·005	0·023	31	72·1
67—91	1·078	1·225	0·147	25	65·8

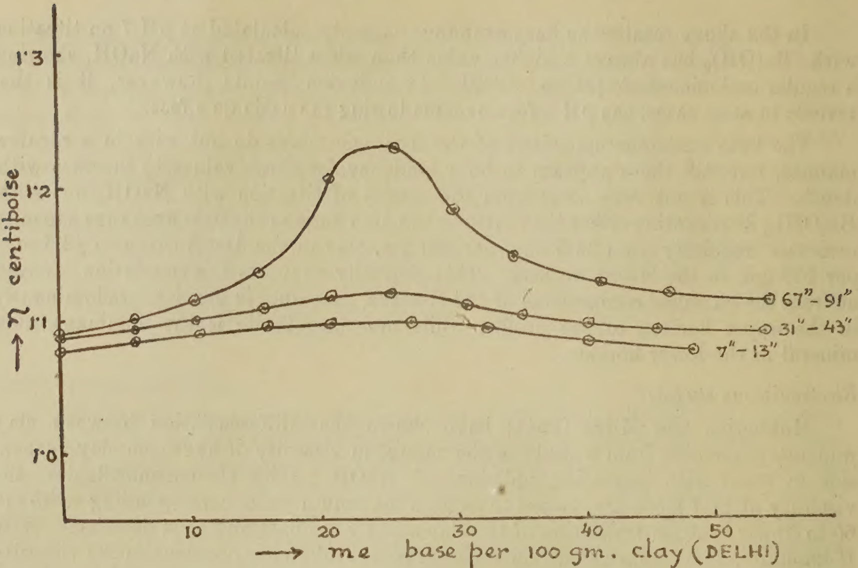
1·3
1·2
1·1
1·0
→ η centipoise
10
20
30
40
50
→ me base per 100 gm. clay (DELHI)
67"- 91"
31" - 43"
7" - 13"

Fig. 1.

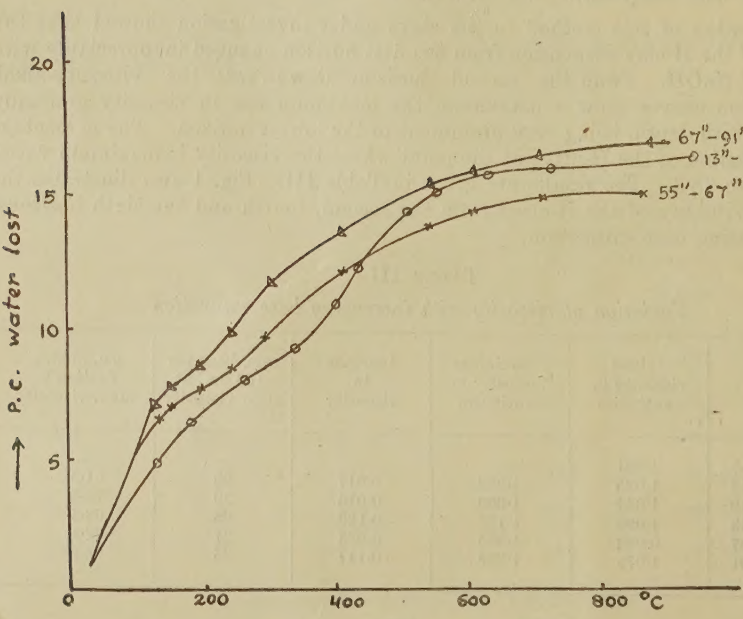
20
15
10
5
→ p.c. water lost
0
200
400
600
800 °C
DELHI
67"-91"
13"- 19"
55"- 67"

Fig. 2.

This fully corroborates the finding that illite is present predominantly in the top horizon, but that with increasing depth down the profile, the clay fraction becomes progressively rich in montmorillonite.

Thermal dehydration studies

Thermal dehydration studies, the results of which are given in Table IV and Fig. 2, lend support to the above statement.

TABLE IV

Total water, adsorbed water and crystal lattice water (as per cent)

Horizon in inches	Total water	Adsorbed water	Lattice water	Temp. in °C, at inflexion
0—7	16·0	8·0	8·0	425
7—13	15·8	8·2	7·6	400
13—19	16·2	8·4	7·8	425
31—43	12·7	5·8	6·9	250
55—67	15·0	7·0	8·0	280
67—91	16·5	7·7	8·8	280

The inflexion in the last three horizons occur at a temperature near about 300°C., the loss of water taking place between 250 and 400°C. For the first three horizons, the inflexion occurs at about 400°C., the loss of water taking place between 400 and 500°C. The amounts of adsorbed water, however, differ much for the various samples. Ross and Hendricks [1945] reported that the loss of water above 250°C. of montmorillonites from different sources ranges between 5 and 8 per cent. Taking into account the loss of lattice water of the clays from the last three horizon samples, the presence of montmorillonite in them is suggested.

H-clays from the first three horizon samples give curves similar to those of kaolinite or illite [Kellog *et al.* 1936 ; Grim, 1937], although the inflexion temperature is slightly lower. Low lattice water of about 7 to 8 per cent which has been found for these clays is not, however, in conformity with that of kaolinite but agrees with that of illite. From the above consideration the predominance of illite in clays from the upper horizon of the profile is suggested.

Karnal profile

Chemical composition of hydrogen clays

The chemical composition of hydrogen clays from different horizon samples are given in Table V.

Table V

Chemical composition of H-clays (per cent ignited basis)

Horizon in inches	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$
0—4	52·66	38·91	2·26	*nil*	0·84	5·28	2·20	2·28
4—26	51·52	41·58	2·76	,,	1·28	3·41	2·02	2·11
26—48	50·43	42·03	1·86	,,	*nil*	3·54	1·99	2·04
48—63	49·35	47·49	1·86	,,	,,	2·31	1·72	1·76
63—80	48·07	42·30	1·84	,,	,,	3·92	1·88	1·93

The composition of these clays are entirely different from those of Delhi soils. In the first and the second horizons, the silica-sesquioxide ratio is two or slightly above it, while it is somewhat less in the lower layers. Silica-alumina ratio similarly has a higher value in the top horizons than in the lower ones. The values of these ratios, as also the individual values of SiO_2, Al_2O_3 and Fe_2O_3, suggest that the dominant mineral present in these clays is kaolinite. The slightly higher values of SiO_2/R_2O_3 and SiO_2/Al_2O_3 ratios in the first and the second horizon samples indicate the presence in these layers of a small amount of a mineral of the montmorillonite-illite group, along with kaolinite, this latter, however, occurring predominantly. Presence of non-exchangeable magnesium to the extent of 0·84 per cent and 1·28 per cent MgO respectively in the first and the second horizons and its absence in the lower layers lend support to the above conclusion.

Presence of an appreciable amount of potassium in these clays will be noticed. These H-clays of particle size 2μ or less are likely to contain some unweathered potash bearing minerals (*e.g.* feldspar) and the potassium found in these clays may have originated from these impurities. Presence of potassium in the clays might, however, suggest the occurrence of illite as in the case of Delhi soils. But the low value of SiO_2/R_2O_3 ratio and the absence of magnesium rule out such possibilities. The

electro-chemical and other properties of the clays discussed later, do not also lend support to the occurrence of illite.

Electrochemical properties

The potentiometric titration curves with NaOH reveal a weak monobasic acid character to hydrogen clays from the first two horizons, the inflexion occurring between *p*H 7·8 and 8·0. With Ba $(OH)_2$, however, a strong monobasic acid character is indicated, the inflexion in this case occurring at *p*H 6·6. The initial *p*H of the sols are in the region 4·5 to 4·9. The nature of the titration curves from the third horizon downwards are entirely different from those from the first two. Both NaOH and $Ba(OH)_2$ curves show weak dibasic acid character of clays, with two well marked inflexions, the first occurring within the *p*H range of 6·2 and 7·6, and the second within 7·1 and 8·8. The initial *p*H of the sols in all cases are well above 5·0. Strong monobasic acid character with $Ba(OH)_2$ with initial *p*H of the sol in the region of 4 to 5 has been observed by Mukherjee and his associates [*loc cit.*] for montmorillonite clays. Kaolinite clays, on the other hand, show dibasic acid character, the initial *p*H of the sol being always above 5. From these observations, conclusions may be drawn that the clay minerals in the first two horizons are montmorillonitic whereas further down the profile kaolinite is present predominantly.

Base exchange capacities of the clays calculated at *p*H 7·0 and at the inflexion points of the titration curves are given in Table VI.

TABLE VI

Base exchange capacity (in m.e. per 100 gm. clay)

Base		Horizon in inches				
		0—4	4—26	26—48	48—63	63—80
NaOH	at *p*H 7	9·5	9·4	6·0	8·2	7·8
	at 1st inflexion	17·6(7·85)*	21·7(8·0)	8·7(7·65)	7·4(6·9)	7·7(6·95)
	at 2nd inflexion	—	—	17·3(8·8)	15·4(7·1)	15·8(8·5)
$Ba(OH)_2$	at *p*H 7	25·4	27·6	7·9	16·6	9·1
	at 1st inflexion	23·3(6·6)	24·6(6·5)	9·1(7·3)	10·8(6·2)	9·4(7·1)
	at 2nd inflexion	—	—	20·8(8·8)	21·4(7·6)	19·5(8·7)

*Figures in brackets indicate *p*H at inflexion points.

Low values of the base exchange capacity of the clays from the third to the fifth horizons and also their dibasic acid nature clearly indicate that the clay minerals of which they are composed are kaolinitic. This is further confirmed by the fact that the ratios of the base exchange capacities as calculated at the two inflexion points are almost equal to 2, a characteristic of kaolinite alone.

In the first two horizon samples, although the nature of the titration curves reveals monobasic acid character of the clays, the base exchange capacities are rather low for pure montmorillonite. It is suggested that these clays are mixtures containing both montmorillonitic and kaolinitic minerals.

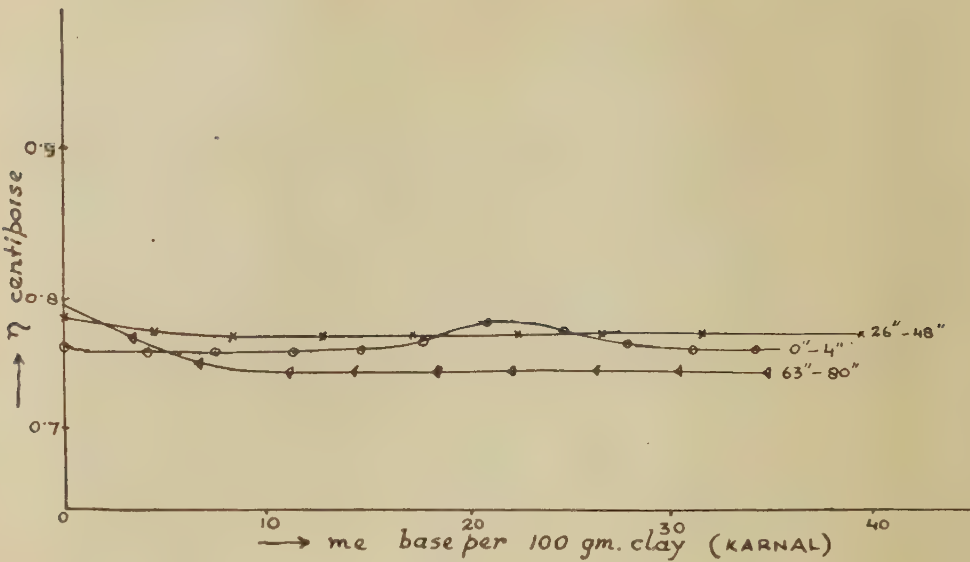
0·9
0·8
0·7
→ η centipoise
0
10
20
30
40
→ me base per 100 gm. clay (KARNAL)
26"-48"
0"-4"
63"-80"

Fig. 3.

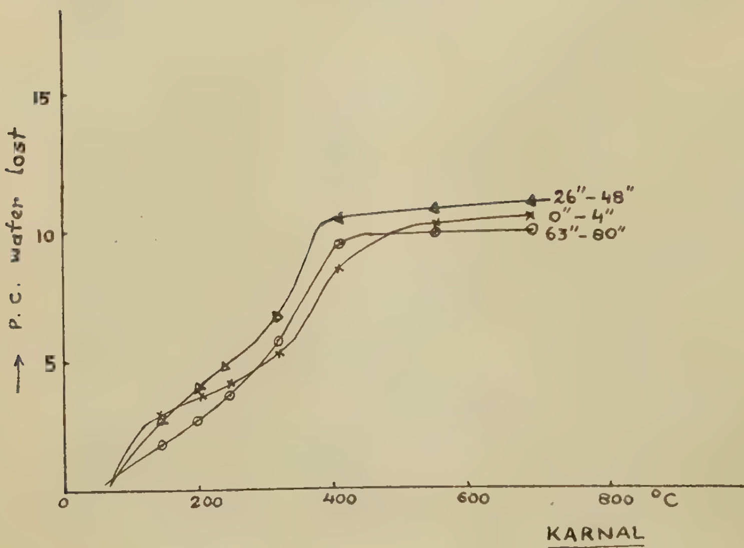
15
10
5
→ p.c. water lost
0
200
400
600
800 °C
KARNAL
26"-48"
0"-4"
63"-80"

Fig. 4.

Electroviscous studies

The mineralogical make up of the clays is also indicated from the variation in their viscosities with increasing addition of caustic soda (Fig. 3). In case of H-clays from the first two horizons the viscosity-alkali concentration curve is almost straight from the beginning up to about 15 m.e. NaOH per 100 gm. clay after which it passes through a slight maximum and then falls again. This rise in viscosity indicates the possibility of the existence of montmorillonitic type of mineral in these clays. Curves for H-clays from the third horizon downwards are practically of the same form as that of pure kaolinite, having a flat run throughout, after a slight initial decrease [Mukherjee and Mitra, 1944].

Thermal dehydration studies

Results of thermal dehydration studies of clays from the first, third and the fifth horizons are given below.

TABLE VII

Total water, adsorbed water and lattice water (as per cent)

Horizon in inches	Total water	Adsorbed water	Lattice water	Temperature in °C. at inflexion
0—4	10·0	4·5	5·5	365
26—48	10·8	4·5	6·3	345
63—80	9·7	3·5	6·2	340

The nature of the dehydration curves of H-clays (Fig. 4) do not show appreciable difference except at the transition to the flat portion of the curve which results from the loss of lattice water. At this point clays from the third and the fifth horizons show a sharp bend, whereas the curve from the first horizon sample is rounded. The curves are more or less of the same form as those of kaolinite or illite. The gradual change in the nature of the curve during loss of lattice water of the clay from the first horizon indicates presence of some montmorillonite in it.

Both the adsorbed and the lattice waters are, however, rather low. In the third and the fifth horizons, the low lattice water (about 6·3 per cent) does not exactly conform to the existence of kaolinites, but other facts, such as higher value of lattice water than adsorbed water and also lower temperature range (300-400°C.) at which loss of water takes place do suggest that kaolinite rather than illite, is present predominantly in clays from lower horizons. Conclusions arrived at from the chemical compositions, electrochemical and electroviscous studies, that clay minerals in the first two horizons are mixtures, containing kaolinite and montmorillonite, while those from the third horizon downwards are predominantly kaolinite are thus coroborated by the thermal dehydration studies.

Conclusion

The climatic condition prevailing in the region of Delhi favours the formation of desert or semi-desert type of soil where physical disintegration is more pronounced than chemical weathering, the latter being impeded due to limited supply of moisture. Vegetation is scanty and the condition existing is unfavourable for decomposition of plant residues, factors which are responsible for low humus and organic matter content of the soil. The soils of this semiarid region are, therefore, liable to erosion both by occasional torrential rain and by dust storm sweeping over the area. The surface soil gets poorer in clay whereas the sub soil becomes enriched mainly by mechanical transportation. In fact, Tamhane and Bhattacharjee [1949] have found only 18 per cent clay in the surface soil while in the subsoil it is 25 per cent.

Mineralogical analysis of this soil [Sen, 1950] shows that the heavy fraction of the fine sand comprises epidote-zoisite 30-50 per cent, hornblende 17-34 per cent, garnet-kyanite-zircon-titanite 9-14 per cent, iron oxides 10-20 per cent, micas 1-2 per cent and tourmaline 1-3 per cent. In the light fraction felspar is present to the extent of about 50 per cent, the rest being quartz. The heavy fraction of the rock from the adjacent Delhi ridge is, however, more simple and comprises mainly tourmaline, muscovite and iron oxides present in the ratio of 20 : 30 : 50. The light fraction is wholly quartz. The analysis thus shows practically no relationship between the parent material of the soil under study and that of the ridge. Sen concludes that these soils are probably aeolian in origin, having been deposited by wind carrying loads of dust from the Rajputana desert. This is supported by the evenness of the grain size, absence of stratification and roundness of the grains.

The chemical analysis of the hydrogen clays show that silica-sesquioxide and silica-alumina ratios from different horizon samples of the profile vary respectively within the range of 2·4 to 2·8 and 3·2 to 3·7. MgO is 0·20 per cent in the clay from the top horizon and 1·13 per cent in the lowest horizon. Potash content decreases downwards from 6·55 to 3·28 per cent K_2O. As has already been pointed out, all these taken together suggest that illite is a major constituent of these clays, which is present roughly to the extent of 80 per cent in the top horizon and 40 per cent in the lowest horizon. The other constituent is montmorillonite whose proportion in the clay increases correspondingly down the profile. This is supported by the value of the base exchange capacity of the clays, which increases gradually with depth.

Viscosity studies of the hydrogen clays also confirm these findings. As in the case of pure illite, very little change in viscosity of the clay suspension of the first horizon with increasing base saturation was observed. With depth, however, the curves show montmorillonitic nature, the maximum rise in viscosity gradually increasing with depth. Full support was also received from thermal dehydration studies.

It is thus concluded that the clay mineral of the Delhi soil is a mixture of illite and montmorillonite, the former being present predominantly in the top layer, but decreasing gradually with depth. Montmorillonite, on the other hand, increases down the profile and is very prominent in the lower horizons.

Karnal soil, though also formed under semi arid condition, differs considerably from that of Delhi. None of them appears to have been formed *in situ*, but while the soil of Delhi, as just described, is probably aeolian, that of Karnal is of old alluvium origin, carried and deposited by the Jumna river. The profile shows a grey brown surface horizon of loam texture followed by a compact of horizon black or brown iron concretions. $CaC0_3$ concretion increases with depth. All these evidences go to place the soil of this region under the world group of brown earth and brown soils as suggested by Satyanarayana and Padhe [1949].

The leaching action seems to be quite active in Karnal soil as the lower horizons appear to consist mainly of kaolinite, whereas the top horizon is a mixture containing both kaolinite and montmorillonite. Chemical and electrochemical properties of clays support this. The high value of silica-sesquioxide ratio, presence of non-exchangeable magnesium, monobasic acid nature of the clays from titration curves, high base exchange capacity all point towards the presence of montmorillonite along with kaolinite in the clays from the top two horizons. The clays from the third horizon downwards consist practically entirely of kaolinite, as judged from their chemical composition, electrochemical and electroviscous properties and thermal dehydration studies. The available evidence shows that the area had long been under forest cover, but at present for a period of over a century it is intensely cultivated and irrigated by the Jumna canal. The physical and chemical processes of weathering may have resulted in the formation of the complete profile, but it is more probable that the lower layer of the soil with its kaolinitic make up was developed much earlier when the climatic conditions were favourable for such formation and the upper soil layer whose mineralogical composition of the clay fraction is different was deposited over it much later.

Summary

Mineralogical constituents of the clay fractions isolated from different horizon samples of two soil profiles, formed under semi arid condition, one from Delhi and the other from Karnal, Punjab (India), have been investigated from a study of the chemical composition of the hydrogen clays, their electrochemical and electroviscous properties and their thermal dehydration. Clays from Delhi soil have been found to be a mixture of illite and montmorillonite, the former being present predominently in the top horizon but decreasing with depth. In the lower horizon montmorillonite is the major constituent. Karnal soil which belongs to the world group of brown earth and brown soils has its clay fraction consisting mainly of kaolinite, but the top horizon up to 26 inches also contains some montmorillonitic type of minerals.

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EFFECT OF DIFFERENT FORMS OF PHOSPHATES ALONE AND IN COMBINATION WITH OTHER MANURES ON BERSEEM AND AFTER EFFECTS ON MAIZE AND WHEAT

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The necessity of phosphate manuring of legumes has been clearly brought out by Parr and Bose [1944, 1945 and 1947] in experiments carried out at the Indian Agricultural Research Institute farm at New Delhi. In 1944-45 another experiment was started to assess the relative manurial value of different forms of phosphates, *viz.*, super-phosphate, bonemeal, ammonium phosphate and basic slag alone and in combination with other manures and fertilizers.

Materials and methods

The experiment was laid out in split-plots with three replications having a plot size of about 1/28·6 acre. The fertilizer treatments were given to berseem in 1944-45, 1945-46 and 1946-47 except that sannhemp green manure treatment was replaced by ammonium sulphate at 50 lb. nitrogen per acre in 1946-47. Basic slag was not applied in 1946-47 due to its non-availability ; consequently its residual effect was studied after 1945-46.

Main-plot treatment per acre

G—Sannhemp green manure
F—Farmyard manure at 120 lb. P_2O_5 containing 200 lb. N.
P—Potassium sulphate at 50 lb. K_2O.
O—No manure

Sub-plot treatment per acre

A—Superphosphate at 120 lb. P_2O_5
B—Bonemeal at 120 lb. P_2O_5
C—Ammonium phosphate at 120 lb. P_2O_5
D—Basic slag at 120 lb. P_2O_5
E—No manure

The cropping system followed during the course of the experiment is detailed below :

Year	*Kharif*	*Rabi*
1944-45	Fallow and green manure	Berseem (manured)
1945-46	Fallow and green manure	Berseem (manured)
1946-47	Maize (grain)	Berseem (manured)
1947-48	Maize (fodder)	Wheat

All manures and fertilizers were applied before sowing berseem. The experiment was conducted in Main Block 8-E.

Yield results

(i) *Direct effect on berseem*

Yields of berseem green fodder obtained during three years are given in Table I.

TABLE I

Yield of berseem green fodder in maunds per acre (1944-45)

	G	F	P	O	Average
A	320·19	242·08	316·95	261·78	285·25
B	308·14	358·20	303·62	253·90	305·96
C	429·01	442·80	376·51	348·47	399·20
D	229·22	316·95	282·76	251·70	270·16
E	244·17	309·41	265·15	246·14	266·22
Average	306·15	333·89	308·99	272·40	..

'F' test was significant at the one per cent level for sub-plot treatments only.
Critical difference at 5 per cent level :
Main-plot treatment 65·80
Sub-plot treatment 70·83
Combination 141·60.

(1945-46)

	G	F	P	O	Average
A	468·99	509·43	507·12	491·47	494·25
B	435·96	496·22	458·10	415·45	451·43
C	551·15	547·79	569·93	551·84	555·18
D	472·70	511·87	486·72	466·67	484·49
E	394·01	489·15	415·68	430·63	432·37
Average	464·56	510·89	487·51	471·21	..

'F' test significant at the one per cent level for sub-plot treatments only.
Critical difference at 5 per cent level :
Main-plot treatment 43·33
Sub-plot treatment 33·47
Combination 66·95

(1946-47)

——	G	F	P	O	Average
A	374·78	346·15	307·45	370·84	349·80
B	289·60	342·33	325·87	287·12	306·23
C	440·71	365·27	400·04	408·61	403·66
D	333·87	338·39	296·55	315·44	321·06
E	238·14	319·50	269·55	253·91	270·28
Average	335·42	342·32	319·89	323·18	..

' F ' test significant at one per cent level for sub-plot treatments only

Critical difference at 5 per cent level :

Main-plot treatment 42·51

Sub-plot treatment 33·96

Combination 67·91.

The best response has been shown by ammonium phosphate in all the years. Superphosphate and basic slag were equally good and definitely superior to ' no manure ' control treatment in 1945-46 and 1946-47. The effect of superphosphate was not fully exhibited by the crop in 1944-45 because it was applied late after sowing due to its late arrival. The response due to bonemeal, though slightly better than the ' no manure ' control, was not significant during 1944-45 and 1945-46. Bonemeal when applied to berseem in 1946-47 following an exhaustive crop of maize gave significant increase in yield over the ' no manure ' control.

Farmyard manure which occupied the first position in three successive years did not show significant increases in yield over other main-plot treatments.

As regards the treatment combinations, ammonium phosphate alone or in combination with farmyard manure, green manure and potash gave best responses. Superphosphate in combination with farmyard manure and ammonium sulphate gave the next best response (1946-47). Combinations of basic slag and bonemeal with the main-plot treatments were not effective.

(ii) *After-effects on maize and wheat*

In order to study the after effects of the manured berseem and the consequent improvement of soil fertility, maize was grown for grain in *kharif* 1946 and 1947 and wheat in *rabi* 1947-48. The maize crop in both the years suffered due to torrential rains. In *kharif* 1947, the crop had to be harvested green as the setting of cobs was adversely affected.

Tables II, III and IV given below show the yields of maize grain, maize green fodder and wheat grain respectively.

TABLE II

Yield of maize grain in maunds per acre for kharif *1946*

—	G	F	P	O	Average
A	25·27	29·18	31·55	28·52	28·63
B	25·94	23·37	29·38	25·85	26·14
C	28·42	28·99	31·38	26·13	28·73
D	30·04	28·71	26·70	28·71	28·54
E	26·80	26·99	26·90	26·42	26·78
Average	27·29	27·45	29·18	27·13	..

'F' test not significant
Critical difference at 5 per cent level :
Main-plot treatment 3·17
Sub-plot treatment 4·39
Combination 9·78

TABLE III

Yield of maize green fodder in maunds per acre for kharif *1947*

—	G	F	P	O	Average
A	168·85	209·29	146·60	160·16	171·22
B	136·28	198·28	174·53	159·11	167·05
C	165·95	182·87	180·78	171·74	175·34
D	192·14	213·93	145·90	144·39	174·09
E	165·72	197·24	144·28	144·86	163·02
Average	165·79	200·32	158·42	156·05	..

'F' test not significant
Critical difference at 5 per cent level :
Main-plot treatment 37·86
Sub-plot treatment 20·21
Combination 40·42

TABLE IV

Yield of wheat C·518 in maunds per acre for rabi *1947-48*

——	G	F	P	O	Average
A	19·19	22·61	17·47	18·46	19·44
B	15·60	18·78	14·37	15·43	16·05
C	20·74	21·63	17·31	20·17	19·96
D	14·62	18·61	13·96	14·70	15·48
E	11·52	15·02	11·26	11·43	12·31
Average	16·33	19·34	14·88	16·04	..

'F' test significant at one per cent level for main-plot and sub-plot treatments.

Critical difference at 5 per cent level :

Main-plot treatment 2·02

Sub-plot treatment 0·91

Combination 1·82

As the maize crop was adversely affected due to heavy rains, it is not possible to draw any definite conclusions from the results presented. The indications are that though the differential responses due to main effects and treatment combinations are not significant, the maize yields have shown almost the same trend as the preceding yields of berseem. The yield was highest in plots receiving ammonium phosphate followed by those recorded from plots treated with superphosphate and basic slag. The after-effect of bonemeal was not encouraging, the yields being as low as in the 'no manure' control plots.

The yields of green maize given in Table III indicate a good response due to the fertility built up by ammonium phosphate followed by basic slag, superphosphate and bonemeal in the order, stated. Farmyard manure showed marked increases over sulphate of potash and no manure treatments. Farmyard manure alone and in combination with basic slag, superphosphate gave better yields than the control.

Highest yields of wheat have been obtained from plots treated with ammonium phosphate followed by superphosphate, bonemeal and basic slag. All the treatments gave substantial and significant increases in yields over the control. Ammonium phosphate and superphosphate were equally effective and superior to bonemeal and basic slag. Differences between bonemeal and basic slag were not significant. Farmyard manure gave significant increases over other main-plot treatments. Ammonium phosphate alone and in combination with farmyard manure or ammonium sulphate and superphosphate in combination with farmyard manure or ammonium sulphate were among the best treatment combinations showing marked effects.

Summary

Among phosphate fertilizers such as ammonium phosphate, superphosphate, basic slag and bonemeal, the best responses were shown by ammonium phosphate as reflected by the yields of berseem and subsequent yields of wheat which was not manured. In the case of maize, though it was adversely affected by rains, the trend of yields was similar to that shown by wheat.

Ammonium phosphate alone as well as in combination with farmyard manure, green manure and potash showed good responses.

Basic slag showed a definite manurial value and can prove a valuable source of phosphatic fertilizer provided cheap arrangement for its grinding can be made.

Bonemeal in general did not show its value as a fertilizer.

The results reported above were obtained under the Delhi conditions where the soil is not rich in nitrogen and available phosphate. The annual rainfall ranges from 20 to 23 inches which makes irrigation imperative for successful crop production.

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ANALYSIS OF SUGARCANE YIELDS

II. RELATIVE INFLUENCE OF SEASON, IRRIGATION INTERVALS, METHODS OF PLANTING AND NITROGEN DOSES ON YIELD AND QUALITY OF CANE

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THE genesis of starting these agronomical experiments has been stated in the first paper of this series. The experiment under review was started in the year 1940 and continued up to 1944. In the previous paper attention was drawn to the peculiar climatic conditions prevailing in Sugarcane tract of the North-West Frontier Province. It was stated, the crop seldom reaches full maturity and that too happens when the season in certain years rapidly cools and is frost free, which conditions hasten the maturing process with some resultant loss in yield. Under such an environment investigation of the effect of such practices which would conduce to early maturity, particularly of plant crop assumes special importance consistent with the high yields aimed at by manuring or regulated irrigation to the crop.

Borden [1944] carried out experiments in pot culture for five years to study the effect of season on the response to be obtained from nitrogen applications. In the Mitscherlich pots the indicator crop planted was *Panicum barbinode*. Eight differentials in nitrogen fertilization were tried on the crop planted on the first of November, February, May and August. The indicator crop was harvested at 90 days. The results showed that May and August sowing utilized the nitrogen more efficiently than November or February sowings. Increasing doses of nitrogen resulted in the larger dry weights. For each additional amount of nitrogen applied there was the corresponding decrease in efficiency. Mean dry weight significantly differed in various years. From the previous investigation [Raheja, 1948] it had been noticed that highest not returns were obtained with 150 lb. nitrogen dose application. The response in sugar and cane yield per acre was significantly greater than with 50 or 100 lb. dose of nitrogen applications. Differences in the yield of cane amongst the various years were significant. It was further pointed out that severity of frost principally determined the juice quality at harvest.

Mathur and Haider [1940] reported that increased application of water increased the utility of nitrogen. They, however, noticed that it was essential to plant early, for, the latter two factors cannot make good the loss by delayed planting of the cane crop. In another experiment they noticed that by increasing the number of irrigations beyond six there occurred a distinct fall in yield. An identical effect on sucrose content in cane was also observed. The lowering effect of nitrogen in sugar yield was also noticed. Similar effect was noticed by Rege and Sannabhadti [1944] i.e., increasing application of nitrogen increased the cane tonnage but decreased

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the concentration of sucrose in the expressed juice. Rege [1937] and Rege and Sannabhadti [1941] observed a significant interaction between nitrogen application and water duty.

Relative irrigation requirements of cane varieties were reported by the author [1944] together with the effect of irrigation interval on cane yield and juice quality. The results had indicated that although cane yield may be lowered by application of irrigation at critical stage of moisture limit, higher sucrose content in cane made up for the loss and the sugar yield per acre was definitely improved.

Seed cane preserved by clamping, to save it from the effect of frost, is used for cane planting. In the clamp, when winters are not severe, the buds tend to sprout. The seed cane has to be carefully planted lest buds be damaged. Method of planting adopted therefore, considerably influences the stand and ultimate yield of the crop. In this multiple-factor experiment, comparison of three different methods of planting were included for study together with three irrigation intervals—weekly, ten days and critical stage of soil moisture limit and three doses of nitrogen 50, 100 and 150 lb. per acre applied to the crop.

The three treatments and their variants are given in Table I below :

TABLE I

Factors of the experiment

Equivalent nitrogen dose as $\frac{A}{S}$	Irrigation intervals	Methods of planting
N_0—50 lb. N per acre	I_0—weekly interval (liberal)	M_0—Flat Planting (local method)
N_1—100 lb. N per acre	I_1—Ten days interval (restricted)	M_1—Furrow uncovered planting
N_2—150 lb. N per acre	I_2—Critical moisture limit (minimum)	M_2—Satts in furrows completely covered and side ridges flattened to permit easy interculture

Various doses of nitrogen in the experiment were applied as ammonium sulphate. This fertilizer was applied and thoroughly mixed in the soil just before planting cane setts in the furrows. A basal dressing of 50 lb. P_2O_5 per acre was mixed with ammonium sulphate before application to the field. Earlier experiments at the Agricultural Research Station, Tarnab, had indicated deficiency of phosphate in the soil. The basal treatment was, therefore, given to obviate the effect of phosphate as a limiting factor in obtaining response of other factors under investigation in this experiment.

The planting of cane was carried out in optimum soil moisture. The temperatures at the time are usually low. Therefore with one irrigation usually the germination was completed. In fact two irrigations were applied uniformly to all plots. The application of water at different intervals was thereafter taken up. It was easy to regulate this interval in seven days and ten days interval treatments. In

the third treatment the basis of water application was the soil moisture status of the soil when it approached critical limit of soil moisture. This limit had been determined by previous experimentation [Raheja, 1944]. Irrigations were applied by constant observations on soil moisture and growth studies on selected plants at regular intervals of three days. The growth in length data recorded in relation to irrigation have already been reported in another publication [Raheja, 1948].

The commonest method of planting canes in the Peshawar Valley is to open out furrows at 3 ft. distance by a *desi* plough. The depth of the furrow in this case hardly exceeded 3½ in. After planting setts these were covered with soil. This was adopted as control (M_0) to compare two other methods of planting canes. In these two methods were opened with the help of a furrow turning plough, the loose earth in the furrows being lifted up with a rake worked by a pair of men. This was the procedure adopted in the first year. In subsequent years the furrows were opened by a ridger attached to a horse hoe. In M_1 treatment the setts were placed at the bottom of the furrow after mixing the manure with the help of a single tined cultivator. The setts were so placed that buds faced sideways. These were covered over with earth half an inch to one inch in thickness. In treatment M_2 the setts were placed exactly as in M_1 treatment. But these were covered over with earth completely by breaking the ridges with the help of a three tined cultivator by running it twice on the ridges as in the Pusa method, [Cliff, 1930]. Immediately after planting canes the land was irrigated in all cases to a depth of 3 in. The furrows in all cases were opened on a thoroughly well prepared land by required cultivations. The layout was a confounded design with two replications, each having three blocks. The second order interactions were confounded with blocks. The ultimate harvested plot size was 66 ft. ×15 ft.=1/44th of an acre. The plot yields were recorded separately for the border area and the ultimate plot. At harvest, in the month of January, cane samples were drawn from each of the plots and juice expressed from them was analysed for juice quality. Fibre was also estimated to work out comparable commercial cane sugar values for various treatments. From the data of cane yields and C.C.S. per cent value sugar yields per acre in each case have been worked out and statistically analysed.

A. *Effect of Environment*

TABLE II

Results of the experiments for the four seasons

Particulars	Season of growth					
	1940-41	1941-42	1942-43	1943-44	Mean	C.D. at 5 per cent
Cane yield md./acre	458·00	634·00	751·00	711·00	638·30	33·62
C. C. S. per cent	8·93	6·29	6·79	10·10	8·03	0·611
C. C. S. yield md./acre	39·60	38·90	49·60	68·80	49·20	5·29

Amongst the years the cane yield varied very considerably. The differences were significant at 1 per cent level of significance. The lowest yield was recorded in 1940-41 and the highest in 1942-43. The low yield in 1940-41 to some extent was due to late planting and poor stand of the crop, as the seed planted had not been clamped. In the remaining three seasons the planting was done in time and the seed used was from the clamped crop. The yields are, therefore, comparable. The differences in yield amongst 1942-43, 1941-42 and 1943-44 were significant. This difference may be attributed to seasonal effect and type of soil on which the experiment was planted. In 1940-41 and 1942-43 the site was identical. Similarly in 1941-42 and 1943-44 the site was exactly the same. Since the layout plan was the same for all the years the differences in yield between 1941-42 and 1943-44 may be explained mainly on the basis of seasonal effect. A summary of mean minimum, mean maximum and total rainfall month by month is given in Table III.

It will be noticed that variation of temperature in the month of March, when the crop is germinating was smaller in 1941-42 than in 1943-44, the ranges being 26·7°F. and 36·7°F. respectively.

Harrington [1923] observed that seeds of several grasses and bulbs germinate much better with favourable alternations of temperature. Later Morinaga [1926] reported that alternating temperatures were essential to germinate the intact seeds of Bermuda grass. Firoz [1931] noticed that the germination of seeds was more quick and more abundant in *Ribes rotundifolia* and *Ribes cynoshati* when subjected to daily alternations of temperatures from 50°F. to 77°F. than when the temperatures remained constant. Flemion [1931] observed that dormant seeds of *Sorbus aucuparia* were rendered active by alternating the temperatures daily or weekly from 1 to 5°C. In the temperature ranges for 1941-42 and 1943-44 the difference in alternating temperatures appears to be more favourable in the latter year so that germination was hastened and crop started early. Besides, it will be noticed that during March and April the rainfall was more in the latter than in the former year. Investigation on growth studies have indicated [Author, 1946] that initial rapidity of growth favourably influences the subsequent growth and cane yield of the crop. Besides, it will be noticed that temperatures during the hot weather, mid-April to mid-July were less severe and during the monsoon season, coinciding with the grand growth period, more rainfall was received in the latter year. It is in consequence of these favourable environmental conditions that the ultimate cane yield was higher in 1943-44 compared to 1941-42, which had similar soil conditions for growth.

The C. C. S. per cent value in cane was the maximum in the year 1943-44 and minimum in 1941-42. The difference in mean values of 1941-42 and 1942-43 were not significant. Das [1931 (1)] had very exhaustively discussed the relationship between climate and juice quality. He observed that quality of juice was influenced by the conditions of growing season as well as weather in the crushing season. In the crushing season excellent juice quality resulted from cool and dry conditions and poor from hot and wet weather. In Peshawar Valley the rate of growth of crop considerably slows down in late September so that weather conditions in October and November have considerable influence on crop maturity. Weather was

TABLE III

Meteorological observations recorded in different years

Month	1940-41			1941-42			1942-43			1943-44		
	Mean Maximum °F.	Mean Minimum °F.	Total Rainfall inches	Mean Maximum °F.	Mean Minimum °F.	Total Rainfall inches	Mean Maximum °F.	Mean Minimum °F.	Total Rainfall inches	Mean Maximum °F.	Mean Minimum °F.	Total Rainfall inches
March	72·8	49·0	3·18	79·4	52·7	0·92	79·6	51·4	0·64	83·3	46·4	1·13
April	83·0	58·1	1·00	91·2	60·9	0·59	89·8	63·4	0·89	86·0	61·9	0·69
May	99·0	71·1	0·06	99·3	68·6	0·55	97·7	66·2	0·78	92·7	62·8	0·43
June	104·5	78·7	0·82	107·6	75·6	..	102·5	71·2	0·07	103·3	68·4	0·19
July	102·8	82·2	0·47	102·9	78·3	0·18	100·0	75·0	4·91	99·0	78·0	2·06
August	96·0	76·7	0·23	98·9	77·5	0·90	98·7	77·6	0·26	94·4	11·1	2·40
September	94·9	70·5	0·17	93·1	66·5	0·52	91·3	67·0	1·39	97·5	73·7	0·11
October	89·4	61·4	..	90·9	61·7	0·20	89·9	55·5	0·15	89·9	64·1	..
November	80·7	48·2	0·04	79·8	44·2	..	83·1	47·0	0·01	82·3	42·3	..
December	69·4	40·5	0·01	70·2	39·6	1·57	64·0	33·0	0·21	71·6	38·9	0·07
January	65·4	38·6	0·30	61·5	38·1	4·04	64·5	38·0	1·83	62·7	36·9	1·10
February	70·9	45·6	0·35	58·0	41·9	4·12	70·5	40·2	0·15	66·7	40·4	3·97

completely dry in the year 1943-44, less so in 1940-41 and least in 1942-43. Discussing the relation of temperature and juice quality Das [1931 (2)] observed that cool nights and warm days have very favourable influence on polarisation and purity per cent. He quoted data reported by Lundegardh that low temperatures at night reduce respiration while optimal temperatures during the day enhance assimilation ; thus, bringing about a net favourable assimilation. The range of temperature in November, 1940 and November, 1943 was 32·5°F. and 40·0°F. and it appears this high range of temperatures and particularly low minimum temperature in November and December which brought about better juice quality in 1943.

The crop was harvested in January every year when the C. C. S. values were worked out. In 1941-42 the season was very wet in December and January. Wet and cool season, according to Das [1931 (1)] conduces to fair and not good or excellent juice quality. He has also pointed out that unfavourable weather conditions in early growth stage, as they existed in May and June, 1941, have deleterious effect on juice quality. It is, therefore, that the cane crop had very poor juice quality in 1941-42. In the following year continuous wet conditions in the crushing season and an appreciable drop in temperatures. (Mean maximum=64·0°F. and mean minimum=33·0°F.) had an adverse effect on cane maturity in spite of the favourable effect of optimum weather conditions in early stages of the plants' life.

The sugar yields per acre were comparable during the seasons 1940-41 and 1941-42. In spite of low yield of 1943-44 crop the sugar yield per acre was very high compared to 1942-43 crop, the difference being about 20 md. per acre. Thus weather conditions in Peshawar Valley have very significant influence on sugar yields.

B. *Irrigation treatments*

Irrespective of the other factors the data regarding influence of irrigation interval on sugar production is given in Table IV.

TABLE IV

Influence of irrigation interval on sugar production

Particulars	Weekly Interval	Ten days interval	Critical stage of moisture interval	C. D. at 5 per cent
Cane yield md./acre	653·7	669·5	590·0	29·12
C. C. S. per cent value	7·79	7·86	8·39	0·53
C. C. S. yield md./acre	47·1	51·9	48·6	5·41

From the data it is evident that ten-days interval treatment gave the highest cane yield per acre. The difference between the weekly and ten-days interval

treatments was not significant. Rege and Wagle [1943] have shown that with higher duty of water, 130 acre inches caused depression in yield. This occurred due to leaching down of soluble nitrogenous compounds. It appears, in weekly irrigation interval treatment a similar effect is noticed. Frequent irrigations had slightly adverse effect on juice quality also. In fact the treatment of applying water at the critical soil moisture limit in spite of yielding significantly lower sugarcane outturn, gave 1·5 md. more sugar per acre than irrigations at weekly intervals, the difference being not significant. The last treatment significantly increased the C. C. S. per cent value in cane plant. While presenting the results of relative irrigation requirements of sugarcane [Raheja, 1944] it had been pointed out that scientific irrigation control on large estates might result in considerable water economy. These results further add confirmation to that conclusion. On the average four more irrigations were needed in ten-days irrigation interval than the irrigations applied at critical stage of moisture limit. It is the cost of this irrigation and the price of 3·3 md. of sugar which will determine the economical procedure of irrigating crop. In *gur* areas where early maturity of cane is the chief consideration the procedure of applying irrigation at critical stage of soil moisture limit is self obvious.

C. *Methods of planting*

The main differences in the three different systems of planting consisted of flat *versus* deep planting and covering the setts (M_0 and M_2 treatments) as against leaving the setts uncovered (M_1 treatment) in the furrow.

TABLE V

Cane and sugar in relation to methods of planting

Particulars	M_0-Flat 3 in. depth covered planting	M_1-Furrow 6 in. depth uncovered planting	M_2-Furrow 6 in. depth covered planting	C. D. at 5 per cent
Cane yield md./acre .	621·5	623·5	669·0	29·12
C. C. S. per cent value	7·97	8·03	8·04	0·53
C. C. S. yield md./acre	48·5	47·3	51·9	5·40

Obviously deep planting of cane and covering the setts results in higher cane and sugar yield than open furrow planting or flat planting. The differences in juice quality were small and not significant. Thus covering the setts to a greater, i.e., up to 5 to 6 inches does not result in any deleterious effect. It appears when the mother shoot emerges it has more of its length in the soil in M_2 treatment and more

of the buds are stimulated to produce early suckers. Sethi [1940] summing up the results of earthing up experiments conducted at various Sugarcane Research Stations in India pointed out the advantages of this practice and stated that it helped the crop in making a vigorous growth. In the covering up of the sett the worked up soil provides a suitable environment for ramification of roots for tapping the soil for plant nutrients in the early stages. Thus in the early stages better nutrition is provided to suckers. The great importance of vigorous early growth had also been stressed by Das [1931] with reference to better quality ratio at harvest. This is borne out by the slightly higher C. C. S. value and significantly greater sugar yield in M_2 treatment compared to M_0 and M_1.

The interaction between methods of planting and irrigation intervals was significant for C. C. S. per cent values and C. C. S. yield per acre of cane crop. The results are presented as under :

Table VI

Interrelationship between methods of planting and irrigation interval—C. C. S. per cent values (a) *and C. C. S. yield—maunds per acre* (b)

Irrigation intervals	Methods of planting M_0	M_1	M_2	C. D. at 5 per cent
Weekly intervals	(a) 8·23	7·22	7·92	(a)0·916
	(b) 48·6	39·6	54·0	
Ten-days intervals	(a) 7·86	8·34	7·38	(b)6·23
	(b) 51·9	54·3	48·9	
Critical stage of moisture intervals	(a) 7·81	8·52	8·84	
	(b) 44·7	48·0	53·1	

C. C. S. per cent value .	I_1	I_2	I_3	C. C. S. yield md./acre .	I_1	I_2	I_3
	8·47	8·10	7·47		52·0	51·3	44·4

In both cases the linear interaction are significant. These results indicate that deeper planting together with minimum irrigation conduce to richer juice, which point to the fact that economy in irrigation water can result by covered furrow planting of cane.

D. Nitrogen doses

A summary of data of nitrogen effect in relation to season is given as under :

TABLE VII

Cane and sugar yields in relation to differential nitrogen fertilizers yield in md. per acre ; (a) *C. C. S. per cent value and* (b) *C. C. S. yield—md./acre*(c)

Cropping season	Doses of nitrogen per acre								
	50 lb.			100 lb.			150 lb.		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1940-41	449	9·35	40·6	427	8·74	36·6	499	8·74	41·6
1941-42	610	5·80	35·8	697	6·25	39·6	595	6·84	41·3
1942-43	696	6·00	41·2	772	7·12	53·9	785	6·99	53·7
1943-44	686	10·10	68·5	712	10·13	65·5	731	10·08	72·3
Mean	611	7·81	48·9	652	8·06	51·5	652	8·16	54·9

A comparison of the cane yields in various years in relation to differential nitrogenous manuring indicated a depression with 100 lb. dose in the first year and with 150 lb. dose in the second year. It is, therefore, that the mean cane yield data for the four seasons did not show significant differences. It is rather difficult to attribute any cause for depressions in yields. In the subsequent two years increasing doses of nitrogen resulted in increased cane yield per acre. The mean values for these data are given as under :

TABLE VIII

Cane yield in relation to nitrogen fertilization

Particulars	Nitrogen doses		
	50 lb.	100 lb.	150 lb.
Cane yield md./acre	691	741	758
Per cent on lowest dose	100·0	107·4	109·8
Sugarcane yield md./acre	54·8	59·7	63·0
Per cent on lowest dose	100·0	109·0	115·0

Additional 50 lb. dose of nitrogen resulted in an increased yield of 50 md. per acre and next additional dose indicated a response of 17 md. only.

In another experiment where nitrogen had been applied in the form of compost the responses with 1st and 2nd additional doses for the same years were 37·4 md. and 29·6 md. respectively over the initial dose [Raheja and Azeez, 1948] (Table VI). A comparison of these figures indicates that probably inorganic nitrogen is more responsive in lower doses that in higher doses compared to farm yard manure. This may be due to leaching out of mobile nitrogen when applied as ammonium sulphate [Rege and Wable, 1939].

A comparison of C. C. S. per cent values in different years indicated differential response to doses of nitrogen. While in the first year 50 lb. dose showed the highest C. C. S. value in the subsequent two years higher doses of nitrogen conduced to greater accumulation of sugar. In the final year the differences were small. While discussing the response of cane yields in relation to weather it had been pointed out that season in the years 1941-42 and 1942-43 had adversely affected the accumulation of sugar in the crop. As against this it appears high nitrogen doses have had a positive beneficial effect because conditions of nutrition were more favourable early in the life of the plant. Mean values for the whole data did not indicate significant differences. On the whole sugar yields increased with higher doses of nitrogen in spite of depressions noted in cane yields in the 1st and 2nd years of the experiment. These results are in accord with those reported earlier [Raheja and Azeez, 1948].

Considering the data for cane yield and sugar outturn together the optimum dose of nitrogen when applied as ammonium sulphate appears to be within the range of 100 and 150 lb. nitrogen dressings per acre.

Summary

Four seasons' conjoint investigations on factors of irrigation intervals methods of planting and nitrogen doses conducted at the Agricultural Research Station, Tarnab, have been reported. The irrigation intervals compared were weekly, ten days and critical stage of soil moisture interval. Shallow flat planting, the commonest practice in the Peshawer Valley, was compared to open furrow planting and covered furrow planting methods. The nitrogen doses dressed at planting were 50,100 and 150 lb. nitrogen per acre as ammonium sulphate. Briefly, the results were as under.

Seasonal factors such as maximum temperatures, minimum temperatures and rainfall affected the outturn of cane and juice quality in the various years. Individual effect of each of these factors has been discussed to show that weather factors have profound effect on sugar yields in any season in the Peshawer Valley.

Cane yield with weekly and ten days interval treatments were comparable. Critical stage of soil moisture interval treatment significantly enhanced the C. C. S. per cent value of the crop. In consequence the sugar yield had comparable value with weekly interval and ten days interval treatments.

Covered furrow planting significantly gave higher cane yield than open furrow or flat planting treatments. The outturn of sugar was also higher but differences

over flat and open furrow planting were not significant. Significant linear interactions between irrigation interval and methods of planting treatments for C. C. S. per cent values and sugar yields per acre were indicated. The richer juices were realised by minimum irrigation treatment together with covered furrow planting compared to flat planting.

On the whole increasing doses of nitrogen exhibited an increase in cane yield. In years when season is unfavourable for normal ripening higher doses had beneficial effect on sugar accumulation in crop. Considering cane and sugar outturn over four years, a dose of 100 lb. nitrogen as ammonium sulphate, is indicated as optimum top dressing.

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GROWTH STUDIES ON *SACCHARUM OFFICINARUM*
III. MANURIAL SERIES

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The concept of the principle of limiting factors was at first clearly stated by Blackman [1905] while working on photosynthesis and external factors of carbon dioxide concentration and sunshine. This principle provided (i) a first approximate to a quantitative analysis of the interaction of the external factors controlling a process and (ii) enabled the determination of the fundamental relationship between any one factor and the rate of the process under investigation. Maskell [1928] referring to his own experimental data drew attention to the working part of this principle and stated that a set of limiting factors acting on a physiological process act as resistances to the potential expression of the rate of physiological process in a normal environment. The relative effect of change in any one of these resistances is at a minimum when the action of remaining resistances is relatively small. But as soon as any one of the resistance becomes dominant its action limits the rate of the physiological process. Ultimately as rated by various resistances, the rate at which the various physiological processes proceed on in a plant determine its yield.

Therefore, in a more general way, in any environment, the crop yield is determined mainly by three variables, namely :

(i) Inherent potentiality of the plant, conferred by its genetical constitution, for crop production ;

(ii) Intensities of positive factors which make positive contribution towards increase in yield ;

and (iii) Intensity of hostile factors which tend to limit the yield.

Briefly then, the inherent power of crop production expresses itself more freely when factors making positive contribution towards yield more liberally act and hostile factors affect the yield in the minimum. Thus every positive and negative factor requires as much of attention as the proper selection of the type of crop plant. Manuring of crops is one of the positive factors for plant growth. In an environment where energy level and moisture level are normal the effectiveness of the application of manures, is inversely proportional to the concentration per unit of space [Willcox, 1929]. So that as the concentration of manures is increased, by equal increments, the yield of the crop is also increased but at a diminishing rate.

In Peshawar Valley cane is an intensively cultivated crop. The main concentration of cane area lies within two districts. The intensity of cane cropping in the Charsadda Tehsil of Peshawar approximates 23 per cent of the cropped area.

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The crop is ratooned at least for three years. Six ratoons are not unusual. Therefore manuring of crop assumes special importance. The studies reported hereafter, extending over a period of three years, were undertaken to understand the effects of basal and top dressing treatments on the relative rate of growth-in-length of the crop. Exponential height growth curves were worked out. The parameter 'A' and 'B' values of these exponential curves have been studied in relation to mean yield per acre and mean C. S. C. per cent values of the crop.

External factors of growth

A. Environment

The data relating to the 'environment and habitat' for the three seasons 1941-42, 1942-43 and 1943-44 have already been discussed by the author. Briefly, therein it was stated, 'The crop season, March 1941 to February 1942, had dry conditions definitely unfavourable during the rapid growing period of the crop, with wet harvest. The crop season 1942-43 was characterised by high relative humidities with low minimum temperatures through most part of the growing season...........Deficient precipitation was again the characteristic of crop season 1943-44'.

B. Chemical analysis of soil

The chemical analysis of soil indicating loss on ignition, Kjeldahl nitrogen, phosphoric acid, potash, etc. revealed that the soil of the two blocks in which the experiments were performed differed only in the quantity of Kjeldahl nitrogen which was 0·058 and 0·126 per cent respectively. In all other constituents there were small differences.

C. Cultural practices

The crop rotation followed in the experimental blocks was as under:

Cowpeas—maize—clover—sugarcane.

The planting of sugarcane was done in the clover crop by opening furrows with a 'desi' plough at 3 feet distance from row to row. The cane was thus planted at a depth of about two inches. It was covered over with earth by manual labour. The crop germinated and began to develop in the clover crop and continued growing till the last cutting of the clover (*Trifolium rasupinatum*) was green manured in mid-May. Basal treatments and top dressings of manures were given to the crop according to the programme described below. The crop was intercultivated twice in the month of June and it was earthed up in the fourth week of July. Thereafter no cultural treatment to the crop was given till the time of harvest.

D. Manurial treatment

(a) *Basal treatments.* The three basal treatments compared in the experiment *basal manuring × top dressing × irrigation interval* series, consisted of (B_0) the common-practice of planting cane in *shaftal* in February and green manuring the last cutting in mid-May; (B_1) winter fallow dressed with 8 cart loads (160 md.) of compost and (B_2) ploughing of *shaftal* without utilizing for green fodder.

(b) *Top dressing.* (i) In the same experiment the top dressing treatments given to the crop were as under :

M_0	I dressing—8 cartloads of compost per acre II dressing—3 cartloads of *khakshara* per acre III dressing—5 cartloads of *dherai* per acre	=100 lb. N per acre.
M_1	I dressing—8 cartloads of compost per acre II dressing—4 cartloads of compost per acre *plus* 4 cartloads of *khakshara* per acre	=135 lb. N per acre.

(*E*) *Irrigation treatments*

I_0—Weekly interval.

I_1—Ten-days interval.

I_2—Critical stage of soil moisture limit [Raheja, 1948].

The treatment M_0 is the standard practice of top dressing sugarcane crop in Charsadda Tehsil of Peshwar District. The Compost is applied about 15 days after the appearance of plants above ground i.e. soon after the germination is complete. The second dose is applied in the end of May when the clover has already been green manured. The *khakshara* for this dressing is the earth from the dilapidated mud huts in villages. The third dose of *dherai*, earth from old historical ruins, is applied at the time of earthing up of the crop in late July. The treatment M_1 is the practice adopted elsewhere, where earth from old ruins (*dherai*) is not available for application. In this treatment only two dressing are given. The first application is of 8 cart loads of manure as in M_0. The second application instead of applying in end-May is given in mid-June. It is claimed by farmers that *khakshara* hastens the availability of plant food when it is mixed with compost. These two treatments were compared against treatment M_2 consisting of an application of 75 lb. each of N and P_2O_5 per acre. Both the fertilizers, ammonium sulphate and *shora* bonemeal were applied immediatly after completion of the crop germination. *Dherai* and *khakshara* normally contain 0·17 and 0·12 per cent nitrogen and 0·5 per cent of phosphoric acid. The two manurial treatments (M_0 and M_1) are the common manurial practices followed in the cane tract. These were compared against M_2 treatment previously indicated from experiments in progress at Tarnab and hence the wide differences in total nitrogen dressed to the crop.

(ii) In another experiment, *nitrogen levels × irrigation intervals × methods of planting*, the three top dressing treatments consisted of three levels of nitrogen applied at planting to the crop. The three levels of application were 50, 100 and 150 lb. of nitrogen per acre in the form of compost with a range of nitrogen from 0·6 to 0·7 per cent on dry weight basis of the stuff. The irrigation intervals followed were the same as for the first experiment. The methods of planting were as under :

M_0—Flat planting and setts lightly covered with earth (Local method).

M_1—Furrow method in which planted setts were lightly covered with a thin layer of soil (Farm practice).

M_2—Setts planted in furrows completely covered and side ridges flattened to permit of easy interculture.

OBSERVATIONS

1. *Growth in height.* As a measure of 'Internal factor' observations at regular intervals were recorded on the growth in height of plants. In the two confounded experiments 10 plants were labelled in each of the nine plots of one of the blocks of a replication of the experiment. Every time the heights were recorded a mean value of the ten heights was worked out. These values served as the basis for working out the cumulative growth in height of the cane stalks, the mean monthly growth values and exponential height growth curves of the plants. The detailed procedure has already been described in the two preceding papers in the series.

2. *Cane yield.* The whole experiment was harvested plot by plot and mean values for the various manurial treatments under consideration have been worked out for each year. These mean values have been converted into yield in mds. per acre for each of the treatments.

3. *Commercial cane sugar per cent values.* Large samples of cane from each of the plots, when it was harvested, were drawn. Besides determining the juice quality, fibre per cent and moisture content in the macerated cane were recorded. From these observations per cent C. C. S. values of the crop from each of the plots were worked out. The procedure for working out C. C. S. per cent value has already been reported [Raheja, 1944] by us.

EXPERIMENTAL RESULTS

A. Basal treatments

1. *Cumulative growth in length.* The recording of growth observations in the experiment *basal treatments × top dressings × irrigation interval* series in the years 1941 and 1942 was taken up early in April. The observations in 1943 were begun in the month of June. In this case, therefore, data for April and May have not been given in Table I.

TABLE I

Summarised cumulative growth in length data in cm.

Crop season	Particular of treatments	Growth months						
		April and May	June	July	August	September	October	November
1941	B_0	22·71	54·38	105·80	177·16	228·02	258·29	265·75±5·12
	B_1	23·25	59·58	110·91	178·93	209·83	236·18	240·06±3·87
	B_2	24·77	58·60	108·82	188·35	227·24	252·80	259·06±4·11

NOTE.—Treatment differences amongst November heights highly significant

Crop season	Particular of treatments	April and May	June	July	August	September	October	November
1942	B_0	16·12	27·45	78·12	151·15	195·81	204·85	211·05±7·32
	B_1	14·40	26·04	83·08	144·38	188·21	196·17	203·35±7·29
	B_2	14·90	26·06	79·39	141·61	188·47	195·71	201·07±5·89
1943	B_0	..	20·93	80·09	135·16	174·76	184·11	186·60±3·29
	B_1	..	21·14	72·13	129·60	176·34	187·58	190·27±4·35
	B_2	..	21·19	82·95	139·69	182·52	193·41	195·86±4·12

NOTE.—Treatment differences between November heights not significant

TABLE II

Exponential height growth curves

Treatment	1941 Equation $H—Ae^{rt}$	1941 S. E. of 'b'	Treatment	1942 Equation $H=Ae^{bt}$	1942 S. E. of 'b'	Treatment	1943 Equation $H=Ae^{bt}$	1943 S. E. of 'b'
$B_0\ I_0\ M_1$	$H=9{\cdot}13e^{0{\cdot}0179t}$	$\pm0{\cdot}000674$	$B_0\ I_0\ M_0$	$H=5{\cdot}27e^{0{\cdot}0186t}$	$\pm0{\cdot}000957$	$B_0\ I_0\ M_1$	$H=12{\cdot}06e^{0{\cdot}0133t}$	$\mp0{\cdot}00114$
$B_0\ I_1\ M_0$	$H=9{\cdot}11e^{0{\cdot}0179t}$	$\pm0{\cdot}001305$	$B_0\ I_1\ M_2$	$H=5{\cdot}68e^{0{\cdot}0173t}$	$\pm0{\cdot}000747$	$B_0\ I_1\ M_2$	$H=11{\cdot}04e^{0{\cdot}0131t}$	$\pm0{\cdot}00115$
$B_0\ I_2\ M_2$	$H=7{\cdot}93e^{0{\cdot}0178t}$	$\pm0{\cdot}000277$	$B_0\ I_2\ M_1$	$H=4{\cdot}96e^{0{\cdot}0177t}$	$\pm0{\cdot}000815$	$B_0\ I_2\ M_2$	$H=11{\cdot}55e^{0{\cdot}0128t}$	$\pm0{\cdot}00160$
$B_1\ I_0\ M_2$	$H=8{\cdot}65c^{0{\cdot}0173t}$	$\pm0{\cdot}000305$	$B_1\ I_0\ M_1$	$H=5{\cdot}60e^{0{\cdot}0188t}$	$\pm0{\cdot}000896$	$B_1\ I_0\ M_0$	$H=11{\cdot}49e^{0{\cdot}0138t}$	$\pm0{\cdot}001091$
$B_1\ I_1\ M_1$	$H=8{\cdot}91e^{0{\cdot}0173t}$	$\pm0{\cdot}001132$	$B_1\ I_1\ M_0$	$H=4{\cdot}99e^{0{\cdot}0177t}$	$\pm0{\cdot}000823$	$B_1\ I_1\ M_1$	$H=7{\cdot}07e^{0{\cdot}0154t}$	$\pm0{\cdot}00146$
$B_1\ I_2\ M_0$	$H=4{\cdot}47e^{0{\cdot}0186t}$	$\pm0{\cdot}002375$	$B_1\ I_2\ M_2$	$H=4{\cdot}57e^{0{\cdot}0174t}$	$\pm0{\cdot}000761$	$B_1\ I_2\ M_2$	$H=7{\cdot}66e^{0{\cdot}0149t}$	$\pm0{\cdot}00116$
$B_2\ I_0\ M_0$	$H=9{\cdot}89e^{0{\cdot}0174t}$	$\pm0{\cdot}000320$	$B_2\ I_0\ M_2$	$H=5{\cdot}50e^{0{\cdot}0173t}$	$\pm0{\cdot}000751$	$B_2\ I_0\ M_2$	$H=11{\cdot}79e^{0{\cdot}0137t}$	$\pm0{\cdot}00171$
$B_2\ I_1\ M_2$	$H\pm8{\cdot}86e^{0{\cdot}0170t}$	$\pm0{\cdot}001249$	$B_2\ I_1\ M_1$	$H=4{\cdot}56e^{0{\cdot}0189t}$	$\pm0{\cdot}000898$	$B_2\ I_1\ M_0$	$H=10{\cdot}37e^{0{\cdot}0140t}$	$\pm0{\cdot}00120$
$B_2\ I_2\ M_1$	$H=8{\cdot}62e^{0{\cdot}0166t}$	$\pm0{\cdot}000783$	$B_2\ I_2\ M_0$	$H=3{\cdot}98e^{0{\cdot}0186t}$	$\pm0{\cdot}001472$	$B_2\ I_1\ M_1$	$H=7{\cdot}73e^{0{\cdot}0151t}$	$\pm0{\cdot}00148$

A comparison of the data of one year against another indicates that growth during 1941 was indicated to be the maximum through all the months. In fact the initial start taken by the crop was kept maintained all through the period of subsequent growth. This start in initial growth was better in 1942 than in 1943. The difference of 5 to 6 cm. in growth in June between the two years increased to about 14 cm. in November. Treatment differences amongst the November heights were significant for the year 1941 only. These were not significant for the next two years. Treatment B_0, the common practice of planting cane in *shaftal* in February and green manuring the last cutting in mid-May, produced the maximum beneficial effect on crop growth. The treatment difference between B_1 and B_2, the ploughing of *shaftal* without utilizing for green fodder, was not significant. B_2 treatment, the winter fallow dressed with 8 cart load of compost, induced the minimum height in plants.

2. *Exponential height growth curves.* The graphic representation of log values of heights at various intervals indicated the curves to have exponential type. The curves were fitted mathematically and these are given as under :

A summary of these growth constants of the exponential curves, mean daily growth rate together with the results of cane yield and C.C.S. per cent values is given in Table III. Irrespective of the other factorial treatment combinations, mean parameter 'A' value was the highest in B_2 and lowest in B_1 treatment in 1941.

TABLE III

Inter-related growth constants. Yield and C.C.S. per cent values

Season	Treatments	Mean parameter 'A' values	Mean daily growth rate	Mean parameter 'B' values	Mean C.C.S. per cent values	Mean yield P.A. maunds
1941	B_0	8·72	0·0175	0·0179	5·66	798
	B_1	7·34	0·0177	0·0176	5·63	832
	B_2	9·46	0·0167	0·0170	5·62	864
1942	B_0	5·30	0·0141	0·0179	6·20	554
	B_1	5·05	0·0146	0·0180	6·32	552
	B_2	4·68	0·0142	0·0183	6·12	548
1943	B_0	11·55	0·0157	0·0131	8·69	578
	B_1	8·74	0·0157	0·0147	8·61	603
	B_2	9·96	0·0161	0·0143	9·07	553

On the other hand mean daily growth rate was the highest in B_1 and lowest in B_2. Correspondingly the mean cane yield was the lowest in B_0 and highest in B_2. The differences between B_2 and B_1 on the one hand and B_1 and B_0 on the other being

almost equal. Mean relative growth rate was the highest in B_0, lower in B_1 and lowest mean value in the case of B_2 treatment. The trend of C.C.S. per cent values were similar.

Mean values for the parameter 'A' of the 1942-Season crop was the highest in B_0 and lowest in B_2 treatment. The difference between B_0 and B_1 almost equalled the difference between B_1 and B_2. Contrarily the mean daily growth rate was the highest in B_1, the values in the other two cases were not very dissimilar. The differences in yield were small. The mean value of the relative growth rate was the highest in B_2 treatment and lowest with B_0 treatment. The difference between B_0 and B_1 was small. Mean C.C.S. per cent value of treatment B_1 was the highest. Thus it is observed that treatments in the crop season 1942 did not show a similarity in the relative growth rate and the C.C.S. per cent values of the crop.

There was no correspondence between crop yields and the parameter 'A' values or mean daily growth rate in respect to the three treatments. Similarly no clear relations between mean relative growth rates and mean C.C.S. per cent values of the crop in the season 1943 were apparent.

A summary of the data relating to basal treatments as given in Tables I to III is given as under :

Statement of data in relation to basal treatments

November heights (Table I)	Mean daily growth rate (Tables I and III)	Parameter 'A' values (Table III)	Mean yield md. P. A. (Table III)	Parameter 'B' values (Table III)	C.C.S. per cent value (Table III)
1941 Sig.	$B_1 > B_0 > B_2$	$B_2 > B_0 > B_1$	$B_2 > B_1 > B_0$	$B_0 > B_1 > B_2$	$B_0 > B_1 > B_2$
1942 Not sig.	$B_1 > B_0 = B_2$	$B_0 > B_1 > B_2$	$B_2 = B_1 = B_0$	$B_2 > B_1 = B_0$	$B_1 > B_0 > B_2$
1943 Not sig.	$B_2 > B_0 = B_1$	$B_0 > B_2 > B_1$	$B_1 = B_0 = B_2$	$B_1 > B_2 > B_0$	$B_2 > B_0 > B_1$

From the above representation of the results, it is evident that various basal dressing treatments did not affect the cumulative growth in length of the crop in a particular way. Depending upon the season the various treatments affected crop growth differently. This is further evident from the responses indicated by the growth parameters in relation to the yield of the crop or its sucrose content.

B. *Top dressing treatments*

With a view to study the response to top dressing treatments two experiments were in progress, namely *basal treatments* × *top dressing* × *irrigation interval* and *nitrogen doses* × *irrigation intervals* × *methods of planting series.* The nature of the top dressing treatments in the former experiment and the quantity of nitrogen doses applied in the latter experiment have already been given in the preceding text. The results of cumulative growth in length and inter-relationship of the parameter values of cane growth constants and the yield and C.C.S. per cent values of the crop are discussed in the following text.

1. *Comparison of local top dressing treatments*

(*a*) *Cumulative growth in length.* The data for the cumulative growth in length for the three seasons is summarised in Table IV. From the data it is evident that crop growth in the formative, grand growth and senescent phases of the crop were different in the three years. The formative stage of crop growth was over by end of May in 1941 season, it persisted up to end of June in the seasons 1942 and 1943. The grand growth stage of the crop was over by end of September in the crop season 1942 and 1943, while in the season 1941 it persisted up to end of October. The accumulated growth in the senescent phase was smallest in November, 1943. It is evident that up to end of May, in the crop season 1941, the differences in accumulated growth were small. In the grand growth period, before earthing up of the crop, a lag was noticed in crop of M_2 treatment. This lag persisted throughout the remaining growth cycle of the crop. The differences in mean height in November, between M_0 and M_1 and M_2 were 45·14 and 17·80 cm. respectively. Compared to the progressive growth with M_0 treatment the cumulative growth with M_1 treatment indicated a lag, in grand growth period after earthing up of the crop. The difference thus evident in November heights between M_0 and M_1 was 27·34 cm.

TABLE IV

Summarised cumulative growth in length data in cm.

Crop season	Particulars of treatments	Growth months						
		April and May	June	July	August	September	October	November
1941	M_0	23·26	59·91	113·87	193·57	235·30	267·29	284·38 ±5·21
	M_1	24·73	61·97	115·32	190·09	224·22	249·26	257·04 ±3·56
	M_2	22·74	50·68	96·34	160·78	205·75	230·71	239·25 ±3·38
NOTE.—Treatment differences amongst the November heights very highly significant								
1942	M_0	15·69	27·31	83·26	142·63	186·10	194·34	200·66 ±6·39
	M_1	14·56	25·42	87·98	159·09	207·67	215·29	221·06 ±6·72
	M_2	15·16	26·81	69·34	135·41	178·72	187·09	193·74 ±6·33
NOTE.—Treatment differences in November heights of M_1 and M_2 were not significant but were significant between treatments M_0 and M_1 and between M_2 and M_0								
1943	M_0	..	21·73	80·69	137·90	185·37	196·12	199·13 ±3·11
	M_1	..	19·47	77·45	132·81	174·45	185·43	187·80 ±3·39
	M_2	..	22·06	77·02	133·73	173·79	183·54	185·79 ±4·79

NOTE.—Treatment differences in November heights between M_0 and M_1 and between M_0 and M_2 were significant

In the crop season 1942 the accumulated growth in the formative period was almost identical up to June. A lag was noticed in the accumulated growth of the crop with M_2 treatment in grand growth stage before earthing up of the crop. This lag persisted right up to the end of the senescent growth phase. A similar lag was

noticed in crop with M_0 treatment but the drop in daily rate of growth was smaller than with M_2 treatment.

Up to the end of the formative period differences in accumulated growth due to the three treatments were small in the season 1943. The growth during the grand growth phase was more pronounced with M_0 treatment than with M_1 and M_2 which maintained an equal rate of growth accumulation month after month. November heights, therefore, indicated significant differences between M_0 and M_1 and M_0 and M_2 treatments.

(*b*) *Exponential height growth curves.* In Table V have been summarised the exponential height growth curve data as derived from Table II of the text, mean daily growth rate, mean yield per acre and mean C.C.S. per cent values of the crop for comparison amongst the treatments in the various crop seasons in which studies were performed.

TABLE V

Inter-related growth constants, yield and C.C.S. per cent values

Crop season	Treatment	Mean parameter 'A' value	Mean daily growth rate	Mean yield per acre mds.	Relative growth rate or 'b' value	Mean C.C.S. per cent value
	M_0	8·72	0·0175	811	0·0179	5·61
1941	M_1	7·34	0·0177	853	0·0176	5·82
	M_2	9·46	0·0167	831	0·0170	5·48
	M_0	5·21	0·01412	419	0·0179	6·50
1942	M_1	5·05	0·01464	571	0·0180	6·22
	M_2	4·66	0·01419	555	0·0183	5·91
	M_0	11·55	0·01571	592	0·0131	8·86
1943	M_1	8·74	0·01573	574	0·0147	8·69
	M_2	9·96	0·01616	568	0·0143	8·82

In the year 1941, in which the cumulative growth in length was greater than in the two subsequent seasons, the values for mean daily growth rate were also higher compared to the other two years. These mean values for M_0 and M_1 treatments were identical and highest in M_2 treatment and lowest in M_1 treatment. The treatment M_1 gave the highest cane yield of 853 md. per acre. This was higher by 22 maunds than M_2 and 42 maunds than M_0 treatments. In relative growth rate M_0 had the highest value and M_2 the lowest. Thus it appears the relative growth rate values did not affect the mean C.C.S. per cent value of the crop.

Mean daily growth rate, it appears, influenced the acre yields of cane in the second crop season i.e., in 1942. The initial rapidity of growth did not influence the

final yield. The relative growth rate also did not show any close correspondence with figures of the C.C.S. values of the crop.

In the third year of the experiment the mean cane yield values neither showed correspondence to the mean daily growth rate nor the initial rapidity of growth values of the crop. Similarly the relative growth rate values of the crop do not appear to have influenced the mean C.C.S. per cent values in relation to the treatments given to the crop.

A summary of the results given in Tables IV and V may be presented as under :

Year	November heights (Table IV)	Parameter 'A' values (Table V)	Mean daily growth rate (Table V)	Yield in mds./ac. (Table V)	Parameter 'b' values (Table V)	C.C.S. ((Table V)
1941	M_0 M_1 M_2	$M_2 > M_0 > M_1$	$M_1 = M_0 > M_2$	$M_1 > M_2 > M_0$	$M_0 = M_1 > M_2$	$M_1 = M_2 = M_0$
1942	M_1 M_0 M_2	$M_0 > M_1 > M_2$	$M_1 > M_2 = M_0$	$M_1 > M_2 > M_0$	$M_2 = M_1 - M_0$	$M_0 > M_1 > M_3$
1943	M_0 M_1 M_2	$M_0 > M_2 > M_1$	$M_2 > M_1 = M_0$	$M_0 > M_1 > M_2$	$M_1 = M_2 > M_0$	$M_0 = M_1 > M_2$

It is evident that neither the November heights, parameter 'A' values nor the mean daily growth rate corresponded to the trends of cane yield. Similarly parameter 'b' also did not indicate correspondence to C.C.S. per cent values in cane so that top dressing treatment did not show an effectiveness in either regulating the relative growth-in-height, initial potential of growth or mean daily growth rate of plants.

2. *Comparison of nitrogenous top dressing treatments*

(*a*) *Cumulative growth in length.* In this experiment the three top dressing treatments compared were 50, 100, 150 lb. nitrogen per acre applied in the form of compost with an average nitrogen content ranging between 0·06 and 0·07 per cent on dry weight basis of the stuff. The observations on cumulative growth in length are summarised as under :

TABLE VI

Summarised cumulative growth in length data in cm.

Crop season	N-doses lb./acre	Growth months: April and May	June	July	August	September	October	November
1940	60	5·70	14·53	42·23	91·03	122·44	141·11	146·18 ± 6·52
	100	6·63	17·14	49·83	100·87	133·36	153·61	158·20 ± 5·63
	150	7·25	20·51	54·29	108·12	135·45	153·33	158·34 ± 6·29
NOTE.—Treatment differences amongst November heights not significant								
1941	50	19·74	45·57	90·38	151·88	191·92	222·00	232·01 ± 5·74
	100	20·18	44·65	96·15	162·74	203·15	233·89	243·42 ± 6·62
	150	19·94	54·93	111·57	178·59	220·33	249·03	261·42 ± 5·52
NOTE.—Treatment differences amongst November heights highly significant								
1942	50	17·46	33·82	95·86	157·78	199·35	207·71	214·27 ± 4·60
	100	18·24	38·37	103·69	161·85	202·01	211·93	218·40 ± 3·02
	150	16·32	36·32	107·21	171·03	210·82	219·68	225·64 ± 4·01

NOTE.—Treatment differences in November heights not significant

TABLE VI—*contd.*

Crop season	N-doses lb./acre	Growth months						
		April and May	June	July	August	September	October	November
1943	..	23·16	95·78	146·25	191·40	201·52	207·05	207·05 $\pm$ 2·92
	..	24·99	101·53	154·84	200·91	213·27	218·04	218·04 $\pm$ 3·85
	..	25·39	97·91	155·55	207·53	216·09	221·54	221·54 $\pm$ 4·42

NOTE.—Treatment differences amongst November heights significant

It is evident from the above data that the formative stage of growth was over by the end of May in the years 1941 and 1942. It was prolonged to end of June in the years 1940 and 1943. This obviously was a seasonal effect. Environmental factors were responsible for prolonged formative periods in the latter two years compared to the former two. Grand growth phase continued up to end of October in the year 1941 and less conspicuously in 1940. This was on the other hand, restricted up to September in 1942 and 1943.

In general, the differences in cumulative growth up to the close of the formative period, in the various years, were not appreciable. The differences in growth began to manifest themselves in the grand growth period of the crop. The trends of results indicated greater accumulation of growth in length with higher dose of nitrogen compared to the lower doses. Although a difference of 12 cm. in November heights was noted between 50 and 100 or 150 lb. in the data for 1940, this difference was not significant. In the next season i.e., 1941 the differences in cumulative growth as indicated by final heights in November were significant only between 50 and 150 lb. nitrogen doses, the differences between 50 and 100 or between 100 and 150 lb. being not significant. Once again in the year 1942 the differences amongst November heights were not significant due to the effect of various doses of nitrogen applied to the crop. In the final year the November heights attained by crop with treatments of 100 and 150 lb. were significantly greater than 50 lb. nitrogen dose application to the crop. Thus in all cases the accumulated height differences between 100 and 150 lb. nitrogen doses were not significant.

(*b*) *Exponential height growth curves.* A summary of the parameters 'A' and 'b of the exponential height growth curves together with the acre yield in maunds and mean C.C.S. per cent values of the crop have been given in Table VII. It will be observed that there was no consonance either between mean initial rapidity of growth and yield or between daily growth rate and yield per acre of the crop raised in year 1940. Highest yield was shown by 150 lb. dose treatment and lowest by 100 lb. dose treatment. The difference in yields between 50 and 100 lb. doses was small. The relative growth rate was inversely related to the crop yields. In the year 1941 the yield realised with 150 lb. dose of nitrogen was lower than 50 lb. dose. This was rather unexpected. The mean relative growth rate values appear to have influenced the mean C.C.S. per cent values. With 50 lb. dose the corresponding values of mean relative growth rate and mean C.C.S. per cent were the lowest ; with 100 lb.

they were medium and with 150 lb. these were the highest. In the year 1942 the crop yields progressively increased with the increase in the doses of nitrogen applied to the field. It appears that neither the initial rapidity of growth values nor the mean daily growth rate values showed a decided effect on the yield. The values of the relative growth rate increased with the larger application of nitrogen. In sugar content with 150 lb. dose there was a depression although the relative growth rate showed a higher value than either 50 to 100 lb. doses applied to the crop.

TABLE VII

Inter-related growth constants, yield and C.C.S. per cent values

Crop season	Nitrogen dose lb. per acre	Mean parameter 'A' values	Mean daily growth rate	Mean Yield P.A. md.	Relative growth rate	Mean C.C.S. per cent values
1940	50	12·11	0·01663	449	0·0127	..
	100	8·80	0·01645	427	0·0140	..
	150	10·72	0·01613	499	0·0133	..
1941	50	8·53	0·01593	620	0·01694	5·81
	100	8·65	0·01649	697	0·01732	6·25
	150	8·47	0·01546	785	0·01790	6·60
1942	50	8·57	0·01434	696	0·01623	6·28
	100	9·42	0·01430	773	0·01660	6·98
	150	8·47	0·01546	785	0·01690	6·60
1943	50	11·58	0·01495	689	0·01314	10·55
	100	12·69	0·01463	712	0·01297	10·31
	150	12·07	0·01503	731	0·01314	10·00

Statement of data in relation to top dressing treatment

Year	November heights (cms.) (Table VII)	Parameter 'A' values (Table VII)	Mean daily growth rate (Table VII)	Mean yield in mds. (Table VII)	Parameter 'b' values (Table VII)	C.C.S. per cent values
1940	Not significant.	50 > 150 > 100	50 > 100 > 150	150 > 50 > 100	100 > 150 > 50	
1941	Significant	150 > 100 = 50	100 > 150 > 50	100 > 50 > 150	150 > 100 > 50	150 > 100 > 50
1942	Not significant	100 > 50 = 150	150 > 50 > 100	150 > 100 > 50	150 > 100 > 50	100 > 150 > 50
1943	Significant	100 > 150 > 50	150 > 50 > 100	150 > 100 > 50	150 > 50 > 100	50 > 100 > 150

From the statement it is evident that there was no correspondence between yield and mean parameter 'A' values or mean daily growth rate of the crop. Relative growth rate values also did not correspond to the mean C.C.S. per cent value of the crop.

GENERAL CONCLUSIONS

In the present paper an attempt has been made to study the influence of basal manuring and top dressing of manures on the relative growth rate, mean daily growth rate, and initial potential of growth in relation to yield and C.C.S. values of the crop.

In the studies already reported in the varietal and irrigation series [Raheja, 1946 and 1948] it has been noticed that initial potential of growth and mean daily growth rate both influenced the yield of the crop and that the correspondence between relative growth rate of the plants and their recoverable commercial cane sugar was very close. In the above series the results have indicated that the basal dressing treatments of green manuring versus compost application indicated similar influences on various growth parameters namely, relative rate of growth, mean daily growth rate and initial potential of growth. From the cumulative growth in length data recorded in Table VI it is evident that 150 lb. indicated better cumulative growth in length than 100 lb. and still better than 50 lb. dose of nitrogen. This is as it should be, for, nitrogen according to Thacher's [1934] classification is an energy storer. Thus Gracanin [1932] observed that curves of growth for the aerial organs rose with the increase in nitrogen in the soil. Crowther [1944] stated that the initiation of meristematic activity is one of the main functions of nitrogen and total growth of plants depends primarily on the rate of development of the leaf surface. The size of the plant, according to him, is thus largely a function of the rate of nitrogen metabolism. Earlier Gregory [1934] stated, leaf growth rate is conditioned almost entirely by the rate of supply of nitrogen. In another connection Gregory [1937] mentioned that external concentration determines the proportion of the uptake of nitrogen by the plants, a low value of nitrogen per cent indicated a season of low nitrogen supply. Das [1936] in Hawaii found that increased application of nitrogen to sugar cane increased the leaf area, the rate of leaf and joint production, rate of elongation of the stem, lodging and tillering and decreased the concentration of sucrose in the expressed sap. Rege and Sannabhadti [1944] concluded from the extensive studies on nitrogen nutrition of sugar cane plant that practically all plant phase are favourably influenced by nitrogenous manuring. It was found to influence beneficially germination, greater tillering, high continuous growth, production of larger number of functioning leaves and ultimately resulting in higher tonnage of the crop. Increasing application, however, decreased the sucrose content in the stalks. With 150 lb. dose it was specifically noticed that the cumulative growth in length during formative and grand growth period was more additive than of 100 lb. and 50 lb. nitrogen doses respectively, while in the senescent phase it was less additive with the former than with the latter two treatments (Table VI).

The values of the initial rapidity of growth, mean daily growth rate and relative growth rate when considered together for the several years showed small differences amongst the treatments.

SUMMARY

The paper briefly outlines the results of growth studies in relation to basal and top dressing manurial treatments in two of the experiments *basal dressing* $\times$ *top*

dressing × *irrigation intervals* and *nitrogen doses* × *methods of planting* × *irrigation intervals*. The data of cumulative growth in length have been compared for the various treatments. Exponential height growth curves were worked out. Influence of the parameters of the fitted curves was studied on ultimate yield and C.C.S. per cent values of the crop. The conclusions may be briefly stated as under :

Differences in mean monthly growth, cumulative growth in length and mean daily growth rates were small amongst the three basal treatments. Similarly consistency was lacking in the results of the initial rapidity of growth values and the relative growth rates of the crop in the different years. On the whole the effect of compost was as good as that of green manuring with *shaftal*.

The results of cumulative growth in length indicated that absolute growth in height of the crop increased with the increase in dosage of nitrogen. In two out of four years the differences were significant.

With 150 lb. dose of nitrogen the cumulative growth in length during the formative period and the grand growth stages was more additive than with 50 and 100 lb. doses, while in the senescent phase it was less additive than with the latter two treatments.

The values of initial rapidity of growth (parameter 'A'), mean daily growth rate and relative growth rate when considered together for all the years indicated small differences amongst the basal and top dressing treatments. These parameters also did not indicate close correspondence to the yield and C.C.S. value in relation to the various treatments applied to the crop.

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PRELIMINARY OBSERVATIONS ON THE INCIDENCE OF *PHENACOCCUS HIRSUTUS* GR. AND ITS EFFECT ON THE GROWTH OF *HIBISCUS SABDARIFFA* LINN. VAR *ALTISSIMA* HORT.

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(With plates X-XI)

HIBISCUS SABDARIFFA var. *altissima* is one of the most important fibre-yielding crops. The crop is attacked by a number of pests, of which *Phenacoccus hirsutus* Gr. is the most destructive, and is responsible for a considerable decrease in the yield of fibre.

Green [1908] reported this pest from an undetermined shrub. Misra [1919*a*, 1919*b*] noted it on the shoots of *Gossypium* sp., *Morus* sp. and *Ficus religiosa*. The pest was also noted by Ayyar [1929] on the leaves of *Ficus indica* and on tender distal shoots of the teak from Malabar. Hall [1917, 1926] reported the same pest from Egypt. Though no record has yet been made of any coccid pest on *H. sabdariffa* var. *altissima*, Ramachandran and Ayyar [1934] referred as many as four other different species of *Hibiscus* as the host plants of coccids other than the one noted on the variety *altissima*.

The present study was undertaken to throw some light on the nature and effect of damage by *P. hirsutus*, its mode of sucking the plant sap, its biology and control, both by chemical and biological methods.

Material and methods

The pest was first observed on *H. sabdariffa* var. *altissima* in some trial crops at Chinsurah Farm in 1948. The pests were collected and multiplied on the same host grown in the laboratory premises for daily observation.

Morphological details were determined from specimens boiled previously in 10 per cent KOH for 5 minutes and staining afterwards with malachite green or Carbol-fuchsin. Mouth-parts were dissected out under the sterioscope and mounted in balsam for observation. For histological study of the affected stem, small pieces were fixed in aqueous bouin's fluid and stained in bismark brown. Similarly affected stem along with the pest with their stylets inserted into the host tissues were also fixed in Alcoholic bouin's fluid and stained afterwards in acid fuchsin to study the *modus operandi* during feeding. Alcoholic bouin's fixative was found to be necessary for removing meals so as to ensure quick penetration of the fixative. Sections were cut at 10 microns thick. For measurement of normal and affected cells, longitudinal sections of normal-cum-affected stem from 1½ month old plants were cut free hand and stained in safranin and light green.

Periodical observations on the seat of infestation and on the morphological changes of the host plant were made in order to determine the locus and estimate the damage caused by the inhibition of the growth of internodes.

To assess the efficacy of different insecticides, randomised replicated petri dish trial was conducted. Atomizer was used for applying the spray. Volume of spray per treatment was determined by gravimetric method. Treatments received their respective insecticidal spray of 0·23 c.c. $\pm$ 0·01 c.c. in petri dishes, each with an average diameter of 12·2 cm. Actual mortality was determined under the sterioscope.

Distribution

The pest has been reported from Tasmania, Egypt, Malabar, North Bihar, Pusa and from Murshidabad, Malda and Bankura districts of Bengal. Recently, the pest has also been noted on samples of *altissim* plants from Vizag district, Madras.

Nature of injury

Nymphs and adult females of *P. hirsutus* during different instars cause frequent injuries to the host by thrusting their long and filamentous stylet fascicle into the deeper cortical layer (Plate X, fig. 1). The stylet fascicle consists of two outer bristles—the mandibles and two inner bristles—the maxillae. The four bristles are firmly held together to form the slender fascicle, which in the adult females measure 1·4 mm. in length and 5 microns in diameter on average. Stylets, when retracted, are received in a loop within an internal pouch—the crumena. The crumena extends backward and obliquely upward into the thorax from the base of the labium (Plate X, fig. 1).

The nature and means by which the delecate stylet fascicle inflicts the injury or penetrates into the host tissues remained obscure until Weber [1928] discussed the subject in details. According to him one of the mandibular stylets thrusts downward at the point of injury. The second mandibular stylet makes another wound and pushes downward until the tips of the two meet each other. Then the maxillary stylets are lowered jointly in between the mandibular stylets. Repeated thrusts in the same manner carry the stylets deep inside the host ti sue. The clasp in the labial groove holds the stylets in position. His view has, subsequently, been accepted by Imms [1934] and Snodgrass [1935].

Observations made on the stylets including their muscle supply suggest that the nature and mechanism of penetration of stylets, in the case of *P. hirsutus*, fall in line with views of these authors.

Effect of injury on the morphological character of the host

Injury, which *P. hirsutus* inflicts on the host, causes the inhibition of the vertical growth of the apical internodes and the attacked region differentiates out by its swelling, shortened internodes and deep green colour. Such swelling and colouration may extend upto the petioles arising from the affected region. Petioles, in such

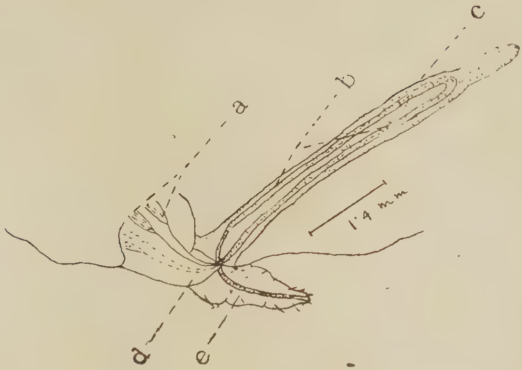

Fig. 1.—Diagrammatic lateral view of the crumena with stylet fascicle. *a*, muscle bands at the base of stylets. *b*, stylet fascicle. *c*, crumena. *d*, labrum. *e*, labium.

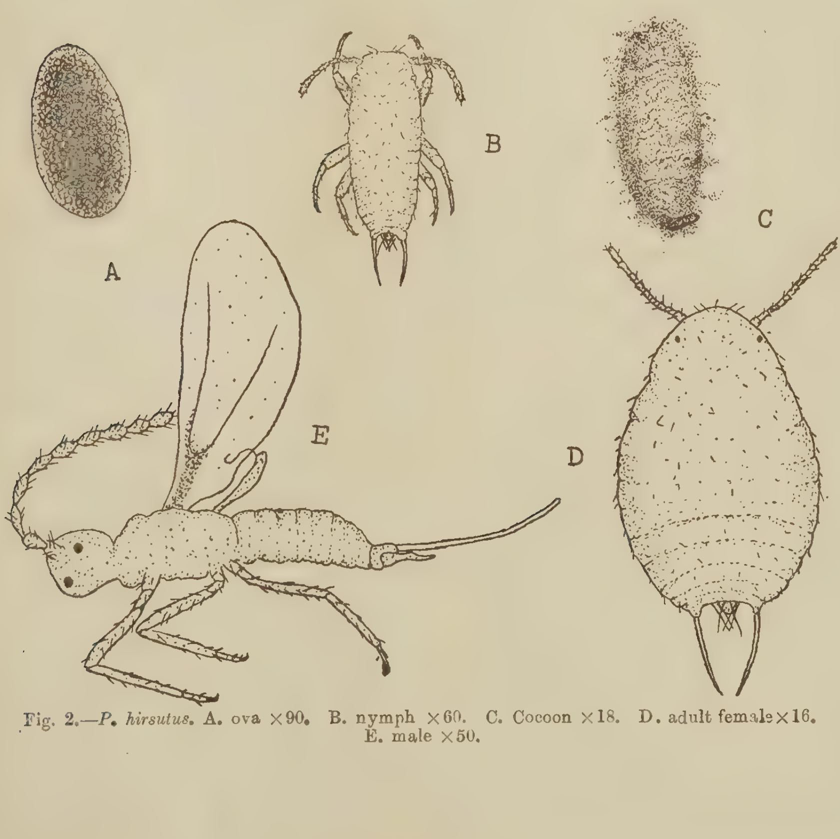

Fig. 2.—*P. hirsutus*. A. ova ×90. B. nymph ×60. C. Cocoon ×18. D. adult female ×16. E. male ×50.

Explanation of Plate XI

Fig. 1. Photo-micrograph showing the stylet fascicle inserted in the cortex (× 200).

Fig. 2. Photograph of the attacked plants.

A, plant with ' bushes ' at the attacked regions.

B, plant dies because of severe attack ; white meals at the top show seat of infestation.

a, ' bush ' developed during first attack ; *b*, attacked pod ; *c*, ' bush ' at top during second attack.

Fig. 3. Photograph of *P. hirsutus* inducing development of swelling and deep green colouration on *altissima* stem.

Fig. 4. Photo-micrograph of T. S. of attacked stem showing ' giant-cells '—a (× 60).

Fig. 5. Predator grub of *Scymnus* (*Pullus*) *pallidicollis* feeding upon the adult female of *P. hirsutus*. (×12).

Fig.2.

Fig.3.

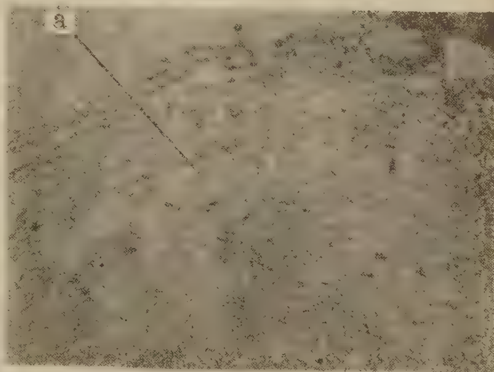

Fig.4.

Fig.1.

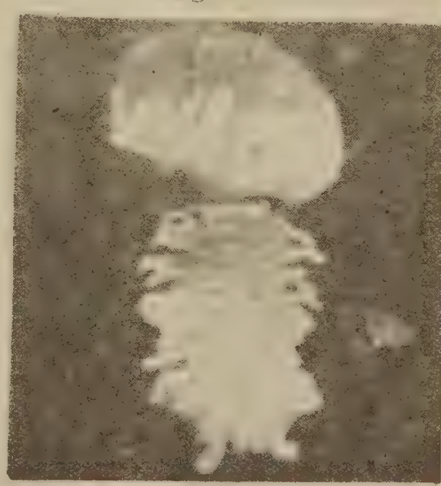

Fig.5.

cases, do not attain their normal length. Leaves from the closely apposed nodes of the attacked region apparently appear, as if, arising from a point and thus giving the plant a typical ' bushy '—top symptom (Plate XI, fig. 2A).

In the cases of severe attack, the drainage of sap is so high that the plants do not survive at all (Plate XI, fig. 2B). During November-December, the pests generally settle in between the calyx whorl and the pericarp and cause frequent injuries to draw their nourishment and thus interferes with the normal development of the capsule. Epicalyx and calyx do not develop to their size and shape, and the persistant calyx, which is normally valvate, crumples away.

When the attack subsides in early season, growth of the apical meristem starts again and one or a number of apical shoots may come out giving the plant ultimately in the latter case, the appearance of a ' broom '-like top.

Effect of Injury on internodal length

Average inhibition of the vertical growth caused by the pest per internode at different stages of growth of the host plant was determined and the Table I shows the decrease of internodal length of young plants by 2·5 cm. and of older plants by 2·9 cm. But the stem diameter of the affected region increases to the extent of 0·2 cm. due to the hypertrophy of cells of different tissues.

TABLE I

Effect of injury by P. hirsutus *on the internodal length*

Age of plant	Numbers of plants examined	Normal region			Affected region		
		Average number of internode (including hypocotyl)	Average length of internode in cm. (including hypocotyl)	Average Stem diameter just below affected region in cm.	Average Number of internode	Average length of internode in cm.	Average stemdiameter in cm.
1½ months (vegetative stage)	21	7	3·1	0·4	6·1	0·6	0·6
4½ months (flowering stage)	29	28·6	4·0	0·4	10·5	1·1	0·6

Laboratory trials have shown that 10 to 12 adult females can arrest the internodal vertical growth and induce the development of deep green colour and swelling after 4 to 5 days from the date of infestation (Plate XI, fig. 3).

Effect of injury on the histological structure

Microscopical studies on the internal structures of the affected region of the host plant shows considerable changes in the tissue structures. There is hypertrophy of the cells in general, cortical and pith cells in particular, in radial direction with the formation of 'giant-cells ' (Plate XI, fig. 4) in most cases in the inner

layer of cortex. Vessels and trachieds of the secondary xylem become less lignified and thin-walled. Table II below shows increase in microns of the affected cells over the normal in radial direction.

TATLE II

Average length and width of normal and affected cells in microns for 100 readings

	Normal				Affected			
	Length	Standard error	Width	Standard error	Length	Standard error	Width	Standard error
Cortical cell . .	123·4	±3·28	25·9	±0·64	105·8	±2·74	60·8	±0·97
Pith cell . .	112·2	±2·94	39·7	±1·33	105·7	±2·78	69·6	±1·27

Seat of injury

Nymphs and adult females are gregarious in habit and show special preference for the nodal joints of the succulent apical region as the seat of infestation than the lamina, petioles, internodes or the basal nodes (Table III).

TABLE III

Frequency of choice for different regions in mean per cent for 1378 nymphs and adult females

Age of plants	Number examined	Apical nodes	Basal nodes	Apical internodes	Basal internodes	Apical leaf petiole	Basal leaf petiole	Apical leaf lamina	Basal leaf lamina	Capsule
1½ months . .	100	51	0·3	1·3	..	16·5	..	30·9	..	..
1½ months . .	15	77·2	..	5·1	..	4·1	..	3·4	..	10·2

Eggs. Eggs are cylindrical in shape with rounded ends and are pink in colour each measuring 0·29 mm. to 0·32 mm. in length and 0·17 mm. in breadth (Plate X, fig. 2A). Incubation period is 7 days at 84±4°F. but varies with the variation of temperature. The period extends upto 14 days in months of December and January. Eggs are laid in batches and the total oviposition period varies from 5 to 8 days.

TABLE IV

Mean oviposition record for 14 females at 84 ± 4°F.

Oviposition range (days)	Total number of eggs (on average)	Mean frequency of oviposition							
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
5—8	197·4	100·4	62·6	20·4	8·2	3·8	1·1	0·6	0·3

Nymphs

After the incubation period is over, eclosion of nymphs starts from ovisac in batches corresponding with the sequence of egg laying. The young tiny nymphs (Plate X, fig. 2B) crawl about for sometime to select a suitable spot on the host to settle down. Nymphs are light pink in colour and secrete white meals and honey and are often visited by ants. Mealy exuviae, which are left on the host plant after ecdysis, give the attacked region a whitish appearance (Plate XI, fig. 2B).

After early instars, nymphs begin to develop distinctive characters associated with sex. Abdominal region of the male nymphs are comparatively slender and taper slightly at the caudal end. They secrete fine white mealy fibres to form cocoon either on the host plant or on the surface of the soil within which are passed the pupal stage (Plate X, fig. 2C).

Adults

Females (Plate X, fig. 2D) are apterous for the whole of their lives and on maturity develop ovisacs within which eggs are laid. A fully developed female is light pink in colour and measures about 3 mm. in length from apex to the end of the anal lobe, while the caudal setae measure about 0·25 mm. Setiferous ring around the anal orifice bears six setae. Legs are single clawed with curved knobbed denticle. Antennae are 9-segmented.

Males (Plate X, fig. 2E) are characterized by their atrophied mouth parts, a pair of delecate wings, halteres and two pairs of ocellanae ; while the abdomen is prominent with a pair of waxfilaments, supported by the anal setae and the aedeagus. Antennae are 10-segmented.

Alternate hosts

Sida rhombifolia and *Hibiscus cannabinus* have also been recorded as alternate hosts of the pest, besides those recorded by previous authors. The pest produces the typical symptoms on these host plants as on *altissima*. The pest during late season also attacks the capsules of *H. cannabinus*, though Crane [1947] reports the only reference to the insect pest of *Hibiscus cannabinus* which might cause some damage specially to plantings grown for seed, is one made by Zegers Ryser. He states that *Dysdercus cingulatus* Fab. causes some damage by boring through the calyx and consuming the milky contents of the young seeds.

Parasites and predators

Parasites and predators are not uncommon and Misra [1919*b*] refers to as many as three species of Chalcidae as parasitic upon the nymphs and females. He also refers to the maggots of Cecidomyiad fly—*Diadiplosis indica*, caterpillars of *Eublemma* sp., *Spalgius epius* as predators upon the pest.

Of the different parasites (Chalcidae) and predators (Coccinellinae) noted so far under the Chinsurah condition, grub of one Coccinellinae bettle *viz. Scymnus* (*Pullus*) *pallidicollis* Muls has been found to feed voraciously upon the eggs, nymphs

and adult females (Plate XI, fig. 5), and appears to be of use for biological control. *Scymnus pallidicollis* Muls. has been found to predate upon Aphids and *Pinnaspis* sp.

Effects of different insecticides on the control measures

For chemical control, different insecticides have been tried in replicated petri dish trial. Of these nicotine sulphate has been found to be very effective.

TABLE V

Effect of the insecticides on the mortality of P. hirsutus

Treatments	Mean mortality per cent
Nicotine sulphate 1·5 per cent solution	82·3
,, ,, 1 per cent ,,	70·9
,, ,, 0·5 per cent ,,	62·3
Lime-sulphur (sp. gr. 1·32) 1 part L. S. : 24 parts water	62·0
Lime-sulphur (sp. gr. 1·32) 1 part L. S. : 48 parts water	48·5
Lime-sulphur dust (3 : 1)	41·8
Guesarol—2 per cent suspension)water-base D. D. T.)	32·9
Agrocide—2 per cent suspension (wettable BHC)	23·2
Gammexane—D.025	21·0
Control	0·0
C. D.	30·6

SUMMARY

Phenacoccus hirsutus Gr. is a very serious pest on *Hibiscus sabdariffa* var. *altissima.* The pest attacks the apical region of the host plant and sucks the plant juice by its long and filamentous stylets. Such attacks arrest the vertical growth of the internodes and the attacked region also develop deep green colour and swelling. Hypertrophy of the cortical and pith cells in the radial direction is responsible for the swelling. The pest chooses more the apical nodal region than the other parts of the host plant for drawing its nourishment.

Various stages of the pest have been described including the mode of oviposition.

The pest can be controlled by Nicotine sulphate spray. Grub of *Scymnus* (*Pullus*) *pallidicollis* Muls. is a voracious predator upon the eggs, nymphs and adult females.

Acknowledgment

Thanks are due to Dr W. J. Hall, Director, Commonwealth Institute of Entomology, London, for kindly confirming the identity of the pest, and to Dr B. C. Kundu, Director of the Institute for his keen interest in the work and for supply of infested *altissima* plants from Vizag district (Madras).

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INHERITANCE OF SEED COAT COLOUR IN GRAM
(*CICER ARIETINUM*)

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A VERY large number of cultivated varieties of gram was collected, studied and employed as parents in the hybridisation as part of the programme of work in the improvement of both quality and quantity of the crop produced in Madras State. Among such extra Indian forms, two from Bari in Italy accessed at Coimbatore as Bari I and Bari II possessed seed coats with deep brown and black colours respectively. The black colour was new and the brown was very much deeper than the CS12 colour grade described by Ramanathan and Balasubrahmanyan [1936]. Since the seed size was big, crosses were effected with improved local varieties for isolating new types with heavier seeds. This paper summarises the results on seed coat pigmentation, seed shape and flower colour recorded for these crosses.

The two Italian varieties when grown at Cotton Breeding Station, Coimbatore, remained poor in both growth and yield. They were therefore sent to the Agricultural Research Station, Nanjanad situated in a cooler region and higher altitude of 6,000 ft. above sea level. The growth was fair and crosses were made with local improved strain 468 and a blue flowered variety T13 described by Shaw and Khan [1931]. The first and subsequent generations of the crosses were raised at Coimbatore and studied.

Factorial hypothesis

The symbolisation of genes affecting the seed coat colour is in accordance with the one adopted by Ramanathan and Balasubrahmanyan [1936]. The hypothesis is restated to serve as background in understanding the factorial laws governing the inheritance of the new characters studied in Italian varieties.

(*a*) The petal colour is controlled by three genes, C, B and P of which C and B are complementary while P is supplementary to B. All the three factors when present together give a pink colour. Factorial constitution CB is blue while all others are white.

(*b*) Five pairs of factors *viz.* Bb, Pp, T^1t^1, T^2t^2 and F^r f^r control the seed coat colours. F^r is hypostatic to B and both factors have pleiotropic effects on plant characters. Factor B imparts a dark olive buff colour; factor P though by itself inactive causes considerable changes in the presence of B; T^1 darkens the colour but has no effect in the absence of P; T^2 has the same action but is influenced by the other factors; F^r has no effect in the presence of B and dilutes the pigmentation otherwise.

(*c*) F^r converts irregular shape into round and gives a puckered surface. B yields round seeds reduced in size when not associated with P and is epistatic to F^r in the absence of P.

(*d*) Two new seed coat factor pairs designated by symbols T^3-t^3 and T^4-t^4 are now described as new. T^4 imparts a black colour to the seed coat irrespective of factorial changes in P whose main effects on the pigmentation of flower as well as shape and size of seed remain unaltered. t^3 gives a brownish tinge of the Bari I type in combinations of factor P. It has however no effect in a base of p and the resultant phenotype is indistinguishable from that of T^3p.

Experimental results

Petal and seed coat colours were the two contrastive characters studied in the four crosses described below. Phenotypic expression and genotypic formulae of the parents and new recovered types as observed in the crosses are given in Table I. The factors segregating in the crosses are underlined.

TABLE I

Factorial constitution of parents and derivatives

Name of variety	Seedcoat colour and grade	Petal colour	Factorial constitution
T13 (A type from Pusa)	CS7 Buffy brown	Blue	$CBpt^1T^2T^3t^4f^r$
468 (A pure strain from Coimbatore)	CS10 Cinnamon	Pink	$CBPt^1T^2T^3t^4f^r$
Bari I (A type from Italy)	CS14 Deep brown	Pink	$CBPt^1T^2t^3t^4f^r$
Bari II (A type from Italy)	CS15 Black	Pink	$CBPt^1T^2T^3T^4f^r$
(Recovered type)	CS7 Buffy brown	Blue	$CBpt^1T^2t^3t^4f^r$
(Recovered type)	CS16 Black buffy brown	Blue	$CBpt^1T^2T^3T^4f^r$

(a) *Bari I deep brown (CS14) × 468 Cinnamon (CS10)* $CBPt^1T^2t^3t^4f^r \times CBPt^1T^2T^3t^4f^r$

The F1 was pink flowered and of seed grade CS10. Only two parental types occurred in the segregating F2 in the proportion of 22 under seed grades CS10, and 5 in CS14. The fit is good for a monogenic ratio, and the segregating factor pair has been styled as T^3-t^3. In the F3 studies all CS14 and three families of CS10 bred true, while five other families of CS10 grade were heterozygous giving a ratio of 76 : 32.

(b) *Bari I deep brown (CS14) × T13 buffy (CS7)* $CBPt^1T^2t^3t^4f^r \times CBpt^1T^2T^3t^4f^r$

The parents differed in petal and seed coat colours. The F1 had pink flower and cinnamon seed coat (CS10) which was different from either of the parents.

In F2, three phenotypes occurred in the following proportion suggesting a modified dihybrid ratio.

Seed grade	Petal colour	Number of plants
CS10	Pink	8
CS14	Pink	3
CS7	Blue	3

An independent segregation should have yielded four phenotypes corresponding to the genotypes of PT^3, Pt^3, pT^3 and pt^3. The merging must be in the p class which will have a blue petal. The genotypes of pT^3 and pt^3 are therefore indistinguishable in phenotypic expression. Unfortunately the studies could not be pursued to third generations as the yields in F2 were extremely poor.

(c) *Bari II black* (*CS15*) × *468 Cinnamon* (*CS10*) $CBPt^1T^2T^3\underline{T}^4f^r \times CBPt^1T^2T^3\underline{t}^4f^r$

The F1 was pink flowered but produced a mixture of types having (1) fully black (2) discontinuously pigmented and (3) sparsely to closely mottled seed coats in one and the same plant. Sparse mottling sometimes took the form of a limited number of black dots on seed which otherwise retained the colour of type 468. The seeds were artificially separated into the three classifiable distinct phenotypes and studied in F2. Their behaviour was identical and every one of the classes threw once again the above three phenotypes in one and the same plant and therefore they are to be viewed as genetically the same. The apparent difference is due to the inadequate black wash over the underlying seed colour.

The F2 gave 526 black and mottled plants and 182 cinnamon coloured plants. Only two parental types were obtained and the fit was good for a monofactorial segregation. All the available plants were studied in F3 and given in Table II.

TABLE II

Number of families studied	Parent grade	Actual number of plants obtained in		Value of P for a 3 : 1 ratio
		CS15	CS10	
51	CS15	773		
102	CS15	1406	486	0·40
63	CS10		1342	

The data satisfied the requirements of a simple mendelian inheritance. The factor in Bari II is styled as T^4 and its possession imparts a black wash to the seed coat.

(d) *Bari II black (CS15)* × *T13 buffy brown (CS7)* $CB\underline{P}t^1T^2T^3\underline{T}^4f^r \times CB\underline{p}t^1T^2T^3\underline{t}^4f^r$

The F1 was pink flowered and produced the same mixture of phenotypes as in the cross studied under (c). Their individual behaviours were again identical. The F2 gave four phenotypes in the following proportion.

Phenotype		Genotype	Number of plants obtained
Seed grade	Petal colour		
CS15	Pink	PT^4	127
CS10	Pink	Pt^4	42
CS16	Blue	pT^4	56
CS7	Blue	pt^4	16

The P value was 0·30 indicating a good fit for a dihybrid ratio. The new genotype pT^4 had blue petals and a black wash over the parental seed colour of CS7 but otherwise retained the round shape and small size of seeds peculiar to Bp combinations as previously recorded by Ramanathan and Balasubrahmanyan [1936].

Discussion

All European forms received and studied were generally bigger than the '*desi*' types in size of the various plant organs and were to a very great extent similar to the Kabuli types described by Shaw and Khan [1931]. They were late in maturity and did not take up kindly to Indian conditions at Coimbatore. There was no difficulty either in crossing the two types or in the study of their subsequent progenies as experienced by Dixit [1932] in Kabuli × *desi* crosses. The difficulty in crossing the two was ascribed to the difference in chromosome numbers. The Kabuli types were supposed to have eight as against seven pairs in the *desi* varieties and the crosses were recorded to have exhibited a good deal of sterility and disharmony usually encountered in interspecific hybridisation. The results of European × *desi* forms (recorded in this paper) and Kabuli × *desi* types (unpublished work of the author) indicate that there was neither disharmony nor sterility, in first to fifth generations and that segregations were perfectly straightforward and normal. This view has been confirmed by Iyengar [1939] who showed that all the types of gram inclusive of Kabuli and *desi* types contained 16 chromosomes in the somatic cells and that they were not different as supposed by Dixit.

The two seed coat colours are new and not recorded before the Indian collection. A type received from Lyallpur and accessed at Coimbatore as 25 had a bluish black seed coat different from that of Bari II. The phenomenon of discontinuous pigmentation of seed coat in F1 has been recorded by Fedotov [1935] in peas in crosses between Abyssinian and European races as well as Urals and European types. It is the result of inadequate or delayed development of the black

pigment. It is likely that the black colour develops late after seed formation and in varieties flowering late during hot weather, the rapid depletion of soil moisture quickens the dryage and maturity inducing incomplete expression of colour.

The distribution of genes is interesting. T^4 was found in the European form but probably was also present in the black seeded Punjab type L25. Factor t^3 noted in the European form was also recorded (unpublished) in the segregating families of Kabuli *desi* crosses studied by the author. The recessive gene might therefore be said to be present in both the big seeded forms of Europe and Kabul. Gram being a hundred per cent self fertilised crop, the existence of a multiplicity of constant varieties should be attributed to recurrent factorial mutations. Phenotypically identical types from Pusa have been shown to be genotypically different by Ramanathan and Balasubrahmanyan [1936] and a maximum mutational rate of 0·0125 per cent has been recorded by the author (unpublished data) in the *desi* types. Dominant and recessive mutations occurred with equal ease.

Popov [1929] regarded *Cicer* as a comparatively young and incompletely differentiated group whose process of individualisation of types both geographically and morphologically still continued, and that due to geographical isolation, races of one species might differ more sharply among themselves than from the neighbouring closely related species. The European, Kabuli and *desi* forms of gram may be viewed as individualised races of *Cicer arietinum* established as a result of such severe geographical isolation.

Summary

Results of crosses between the Indian and Italian forms are described.

Two new seed coat colour factors T^3 and T^4 are demonstrated. Factor t^3 alters cinnamon coloured CS10 to deep brown CS14 but has no effect in Bp combinations. T^4 imparts a black colour irrespective of the presence or absence of P.

Kabuli forms contain the factor t^3 as disclosed in their crosses with *desi* types.

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STUDIES IN STORAGE OF *GUR*

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In a previous communication [1949], the authors reported a method of *gur* storage under a blanket of ash which maintained the product in good condition all through the period of storage. The stored material, however, suffered some loss in weight, although the magnitude of loss was considerably less than in other methods in vogue. In a later paper [1949], preliminary experiments on suitable moisture-proof wrapping materials and containers for *gur* storage were described, some of these having proved quite effective on a small scale. The two types of storage method appeared to offer excellent possibilities for practical application, if suitably adapted to fit in with commercial requirements. The present investigations were, therefore, undertaken with the above end in view and the immediate objective of—(i) modifying the ash storage method so as to eliminate losses in weight of material and (ii) examining on a large scale the commercial possibilities of different kinds of moisture-proof wrapping materials and containers for *gur* storage.

Experimental

(a) *Methods under examination*

(i) *Modified ash storage method.* It had been observed in earlier experiments [*loc. cit.*] that notwithstanding the weight loss suffered by *gur* stored under ash, the shape and volume of the blocks remained unaffected and at the same time, their colour changed to a considerably lighter shade. This behaviour suggested the possibility of a certain amount of drainage of the matrix fluid (molasses in portion) as a result of direct contact with the hygroscopic ash which might account for loss in weight without change in shape and volume accompanied by a simultaneous improvement in colour. In order to prevent weight losses, therefore, some modification was obviously called for which could stop the drainage of matrix fluid and it was considered worthwhile to examine if this could not be affected by removing the *gur* from direct contact with ash. Accordingly a modified ash storage method was under examination wherein *gur* blocks were stitched inside a covering of gunny and then embedded in ash in the usual manner.

(ii) *Moisture-proof wrapping materials and containers.* Experiments on these were conducted on a larger scale, both at the Research Station and under actual market conditions at two important centres in the province, *viz.*, Bihta (District Patna) and Gaya. The following methods were under examination :

1. Blocks stitched in gunny bags coated with—

   (*a*) Zinc white paint, (*b*) a preparation of low grade lime and glue (crude gelatine), (*c*) a preparation of linseed oil and glue, (*d*) paraffin wax,

(*e*) plaster of Paris and (*f*) Mixture of plaster of Paris and low grade lime.

2. Blocks wrapped in paraffin wax coated paper and stitched in gunny.
3. Blocks stitched in drill cloth bag coated with—

   (*a*) Zinc white paint, (*b*) a preparation of low grade lime and glue, (*c*) paraffin wax, (*d*) plaster of Paris and (*e*) mixture of plaster of paris and low grade lime.
4. Blocks kept in closed dealwood box and the latter stitched over with coaltar coated gunny.

(b) *Practical details*

Some practical details concerning those of the wrapping materials and containers which proved moisture-proof and effective are given below in brief.

Method 1 (a) : Zinc white paint is diluted with linseed oil to a suitable consistency and applied to gunny in two or three successive thin coats with intervals for drying. Final drying before use takes four or five days' time. For painting a bag of one maund capacity, 1 lb. each of paint and oil are required, which cost about Rs. 1-5-0.

Method 1 (c) : Glue is soaked in an equal quantity of water and removed before it has lost its primitive form. The swollen glue is dissolved in linseed oil (same quantity as the glue) with the aid of heat until a jelly is formed. This is applied in two successive thin coats on the fabric and allowed to dry. A bag holding one maund *gur* requires 2/3 lb. each of glue and oil, the cost amounting to about Rs.1-7-0.

In each of the above methods, the bag is stitched in a very close and tight fashion and the stitched portion painted with a layer of the coat.

Method 2 : Large sheets of newspaper are coated on one side with a single application of molten paraffin wax and blocks well packed in these are stitched in an outer covering of gunny. For storing a maund of *gur*, $\frac{1}{2}$ lb. of paraffin wax is necessary which costs about 8 annas.

(c) *Procedure*

Various samples of *gur* were stored by the different methods and examined before, after and periodically during storage in respect of general features and different analytical criteria so as to assess their quality level at various stages. Details have been described in a previous communication [*loc. cit*]. Typical data pertaining to the methods which proved effective are presented in Tables I to III, those for the unsuccessful ones being omitted for brevity.

Discussion

(i) *Medified Ash Storage Method.* A perusal of the typical results incorporated in Table I will show the performance of the modified ash storage method against the original method of storing *gur* blocks directly under ash. It would appear

TABLE I

Showing properties of gur *stored by the modified ash storage method against the original ash storage method*

—	Sucrose	Glucose	Moisture	Milli eq. acid in 100 gm.	Per cent loss in weight	General features
			(a) Modified ash storage method			
Initial	76·64	3·02	6·62	17·3	..	Hard, crystalline, taste good, colour dark brown
Final	76·14	3·58	5·78	17·8	..	do.
			(b) Original ash storage method			
Initial	77·26	3·21	6·62	16·8	..	Hard, crystalline, taste good, colour dark brown
Final	78·70	3·27	4·10	18·3	12·0	Hard, crystalline, taste good, colour whitish brown

TABLE II

Showing properties of gur *stored in moisture-proof wrapping materials and containers*

—	Sucrose	Glucose	Moisture	Milli eq. acid in 100 gm.	Per cent loss in weight	General features
			A. Gur *blocks stitched in gunny bags coated with zinc white paint*			
			(a) *At the Research Station*			
Initial	77·26	3·21	6·62	16·8	..	Hard, crystalline, taste good, colour dark brown
Final	76·34	4·40	7·46	21·3	..	do.
			(b) *At Bihta*			
Initial	70·40	8·80	4·94	22·1	..	Hard, crystalline, taste good, colour dark brown
Final	69·68	8·32	4·94	22·6	..	do.
			(c) *At Gaya*			
Initial	72·84	6·41	4·10	25·6	..	Hard, crystalline, taste good, colour dark brown
Final	72·26	6·41	4·94	26·6	..	do.
			B. Gur *blocks stitched in gunny bag coated with linseed oil-glue preparation*			
			(a) *At the Research Station*			
Initial	76·64	3·02	6·62	17·3	..	Hard, crystalline, taste good, colour dark brown
Final	75·50	7·70	7·46	24·3	..	do.

TABLE II—*contd.*

Showing properties of gur *stored in moisture-proof wrapping materials and containers*

—	Sucrose	Glucose	Moisture	Milli eq. acid in 100 gm.	Per cent loss in weight	General features
B. Gur *blocks stitched in gunny bag coated with linseed oil-glue preparation*						
(b) *At Bihta*						
Initial	65·60	8·55	6·62	23·6	..	Hard, crystalline, taste good, colour dark brown
Final	65·44	8·55	6·62	23·6	..	do.
(c) *At Gaya*						
Initial	69·60	7·00	5·78	24·1	..	Hard, crystalline, taste good, colour brown
Final	68·40	7·35	6·62	25·6	..	do.
C. *Blocks wrapped in paraffin wax coated paper and stitched in gunny*						
(a) *At the Research Station*						
Initial	77·26	3·21	6·62	16·8	..	Hard, crystalline, taste good, colour dark brown
Final	76·80	6·16	6·62	19·8	..	do.
(b) *At Bihta*						
Initial	64·04	8·80	8·30	25·6	..	Hard, crystalline, taste good, colour dark brown
Final	63·20	8·32	8·30	24·1	..	do.
(c) *At Gaya*						
Initial	68·92	8·55	7·46	22·6	..	Hard, crystalline, taste good, colour brown
Final	69·12	8·55	6·62	22·1	..	do.
D. *Blocks stitched in ordinary gunny (control)*						
(a) *At the Research Station*						
Initial	76·06	3·08	5·78	17·8	..	Hard, crystalline, taste good, colour brown
Final	68·56	8·55	16·66	38·6	23·8	Partly liquefied ; bad smell and taste, heavy fungus growth
(b) *At Bihta*						
Initial	76·20	7·00	3·26	23·6	..	Hard, crystalline, taste good, colour dark brown
Final	62·64	10·26	13·33	29·6	26·4	Very soft, molasses running
(c) *At Gaya*						
Initial	67·36	9·62	8·36	28·6	..	Hard, crystalline, taste good, colour brown
Final	61·22	12·23	13·33	25·6	22·4	Very soft, molasses running

TABLE III

*A statistical comparison of the changes in properties of gur stored by different methods**

(Data on experiments at the Research Station : varieties : Co. 453, B.O. 3)

Methods* Character	I	II	III	IV	V	+	C.D. at 5 per cent	C.D. at 1 per cent	Conclusions.
1. Sucrose	100·88	99·41	98·65	99·30	99·96	0·8869	0·6125	0·8140	5 per cent I V II IV III
									1 per cent I V II IV III
2. Glucose	1·9416	2·0368	2·0641	2·2209	2·1276	0·0790	0·0559	0·0743	5 per cent IV V III II I
									1 per cent IV V III II I
3. Moisture	1·8896	2·0184	2·0685	2·0633	2·0421	0·0595	0·0422	0·0560	5 per cent III IV V II I
									1 per cent III IV V II I
4. Milli eq. acid in 100 gm.	2·0279	2·0125	2·0738	2·0531	2·0405	0·0233	0·0164	0·0218	5 per cent III IV V I II
									1 per cent III IV V I II

*Mean figures for the whole storage period have been expressed as percentages of the initial figures and except in case of sucrose, analysed after logarithmic transformation—the results relating to transformed varieties.

The different methods have been numbered in the table as follows :

I. Original ash storage method II. Modified ash storage method III. Blocks stitched in gunny bag coated with zinc white paint. IV. Blocks stitched in gunny bag coated with linseed oil-glue preparation. V. Blocks wrapped in paraffin wax coated paper and stitched in gunny.

that *gur* blocks stitched in gunny and then kept under ash also maintained their quality, no deterioration being observed in respect of hardness, taste, etc. Further, weight losses are absent, in contrast to losses of the order of 12 per cent suffered in the original method. The modification is therefore a remarkable improvement and constitutes a cheap and effective method of storage. Besides, the modified method does not involve direct contact of *gur* with ash, the need for cleaning the surface of the blocks being thus obviated.

(ii) *Moisture-proof wrapping materials and containers.* Only three of the methods in this category proved effective enough in maintaining quality and weight of material intact through the period of storage, all others showing deterioration of *gur* by the end of August. The three effective methods were :

Method 1 (a) : Blocks stitched in gunny bag coated with zinc white paint.

Method 1 (c) : Blocks stitched in gunny bag coated with a preparation of linseed oil and glue.

Method 2 : Blocks wrapped in paraffin wax coated paper and stitched in gunny.

Method 2 above was a modification of a method first tried on a laboratory scale in the Indian Institute of Sugar Technology, Kanpur and later tested under the more humid conditions at Pusa by the present authors. Although waxed paper wrapping (as originally used) was quite effective, it was often damaged by rats and ants with consequent deterioration of *gur*. Some kind of protection for the paper was therefore needed and this was provided by the outer covering of gunny which prevented damage by rats and ants.

It thus appears that all the three methods are satisfactory and may be used with advantage. Typical data (collected both at the Research Station and in *gur* markets) are presented in Table II along with the observations on the usual market method of storage in ordinary gunny bags for comparison. Data on methods which proved ineffective are omitted.

It now remains to estimate the cost of storage by the three methods and in this connection it has to be stated that the bags, as coated in methods 1(a) and 1(c), are of a semi-permanent nature and at the end of one season's use, show no sign of wear and tear. On a modest estimate of their durability as three seasons, the average cost of storage per maund of *gur* works out to about 7 and 7½ annas respectively. In case of method 2, the wrapping paper can be used for one season only and the cost of storage would thus amount to 8 annas per maund. There is, therefore, very little to choose between the three methods. Means for further reduction in cost are under examination.

(iii) *Statistical comparison of the properties of* gur *under different methods of storage.* A statistical comparison of the changes in the properties of *gur* stored by different methods has been shown in Table III on the basis of experimental data collected at the Research Station. It would appear therefrom that, in general, the original method of ash storage maintains a distinctly superior level in respect of chemical criteria, as compared to other methods. As between the rest, the differences are not systematically in favour of any method. Considering the fact that the average sucrose (polarisation) level maintained during the storage period lies between 98·65 and 100·88 per cent of the original values in all cases, the performance of all the methods must be regarded as very satisfactory. Statistical analyses of data for the three methods under examination in *gur* markets reveal no significant differences between them, thus showing that their performance is on the same level. The figures are omitted for brevity.

Summary

The authors' method of *gur* storage in a blanket of ash has been modified so as to eliminate losses in weight during storage. The modified method (wherein *gur* blocks stitched in gunny are embedded in ash) maintains the product intact in respect of quality and quantity. This offers a satisfactory solution of the storage problem.

Certain moisture-proof wrapping materials and containers for *gur* storage are described which also produce the desired result. Their relative economics

are discussed and suitability under actual market conditions demonstrated. These represent an alternative procedure for *gur* storage.

Acknowledgments

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A STATISTICAL STUDY OF RAINFALL AT INDORE

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(With five text—figures)

THE influence of weather factors such as rainfall, temperature, humidity, etc. on agricultural crops, has been recognized universally and attempts have been made in the past to study their effects on different crops. Amongst these factors, rainfall is of primary importance for the growth of crops raised on unirrigated lands. In studying the effect of annual rainfall on crops, not only the total amount of annual rainfall, but its distribution during the season should receive attention as being equally important. For instance, it has been observed at Indore that good yields were obtained even when the annual rainfall was as low as 18 in., against an average of about 35 in., due to its favourable distribution. Similarly, the response of wheat crop to green manuring, was conditioned by the amount of rainfall received during the months of September—October [Panse, 1947]. With this importance of rainfall, a critical analysis of its distribution and seasonal trends in a given area would provide information of high agricultural value. Results of a statistical study of the rainfall at Indore are described in the present paper.

Material

The material for the present study was collected from the daily records of rainfall measured at the Institute of Plant Industry, Indore. The amount of rainfall received during the past 24 hours is recorded daily at 8 a.m. These records are available from 1 January 1924. For the purpose of the present study, data for 24 seasons, from 1924 to 1947, have been used.

In addition to these data, records of annual rainfall for the same period of years were procured from the King Edward Memorial Hospital, Indore and the Office of the Director of Land Records, Indore. These two sets of data which were obtained from rain-guages located within a distance of about 2 miles from the Institute were compared with the annual rainfall recorded at the Institute. A detailed statistical study of the intra and inter-seasonal variation in rainfall at Indore was, however, carried out only with the Institute data.

Method

The method adopted in the present investigation was the one developed by Fisher [1923] in his study of the influence of rainfall on the yields of wheat crop at Rothamstead.

The daily rainfalls from 1 January to 31 of December for each season were grouped into 52 weekly totals, each week consisting of 7 days, except that the last (52nd) group of a non-leap year and last two (51st and 52nd) groups of a leap-year,

included 8 days. The weekly totals of rainfall in inches recorded at the Institute for the period of 24 years under study are given in Appendix A.

In the weekly grouping of data, use of a calendar year starting on 1 January, instead of a year starting with the beginning of monsoon which has been employed by some workers [Kalamkar, 1940 ; Koshal, 1937] has been preferred in the present study and is recommended for adoption generally, in order that statistical results of such studies might become strictly comparable, as there is no fixity in the date of the onset of the monsoon. The starting point of the monsoon has also to be determined arbitrarily and is liable to considerable fluctuations from season to season. In order to study the distribution of rainfall in each season, polynomial curves of the fifth degree were fitted to the weekly totals of rainfall values. The method of fitting such curves has been illustrated by Fisher and Yates [1948]. With such a curve the variation in the distribution of rainfall in any season can be represented by the following analysis of variance.

Variation due to	D. F.
Linear component of the polynomial	1
Cubic component of the polynomial	1
Quadratic component of the polynomial	1
Quartic component of the polynomial	1
Fifth degree of the polynomial	1
Total accounted for by the polynomial	5
Residual	46
Total	51

The analysis of variance shows the extent of the closeness of the fit of the polynomial curve to seasonal distribution of rainfall by splitting the total seasonal variation into two components : (1) the variation absorbed by the curve and by each coefficient of regression and (2) the variation that could not be accounted for by the curve.

The orthogonal polynomial curve fitted to the weekly totals of rainfall could be represented by the equation.

$$Y=A+B\xi_1+CZ\xi_2+DZ\xi_3+EZ\xi_4+F\xi_5,$$

where A is the average weekly rainfall in a season and B, C, D, E and F are the five regression coefficients of linear to fifth degree terms respectively and ξ_5 are the orthogonal functions of t, the time interval.

Twenty-four values of each of the above six constants were thus available corresponding to 24 seasons. These constants varied from season to season due to the differences in the distribution of rainfall within each season. The average values of each of the six constants for the entire period of 24 years were then used to obtain

the equation for the average distribution of the weekly rainfall over this period. The actual values of the various constants calculated for each season and their averages are given in Appendix B.

RESULTS

The results obtained from the investigation can be described under two heads :

(*a*) Alternative approaches to the study of the seasonal variability of the rainfall distribution.

(*b*) Results concerning the distribution and seasonal trends in the rainfall at Indore.

(a) *Alternative approaches to the study of variability*

(1) *Fitting of higher degree curves.* It has been mentioned above that polynomial curves of the fifth degree were fitted to weekly rainfall totals for each season. The main reason for limiting the curve to the fifth degree was that tables for the ξ coefficients are available only up to the fifth degree, and these tabulated values reduced the labour of computation as compared to the summation method used earlier in such problems [Fisher, 1946]. The percentage sum of squares accounted for by the fifth degree polynomial is shown in Table I.

TABLE I

Year	Percentage variation accounted	Year	Percentage variation accounted
1924	37·8	1936	14·6
1925	32·9	1937	33·1
1926	42·3	1938	37·6
1927	39·5	1939	27·7
1928	16·2	1940	39·1
1929	35·3	1941	24·2
1930	32·8	1942	35·6
1931	51·2	1943	28·5
1932	26·9	1944	45·2
1933	34·1	1945	57·1
1934	34·6	1946	29·5
1935	36·2	1947	47·2

It will be seen that the percentage variation in the rainfall distribution accounted by fitting 5th degree polynomial curves ranged from 15 to 57 and averaged to 35. This reduction which corresponds to a multiple correlation coefficient of 0·59

indicated that the curve was not a good fit. The average percentage reduction accounted by the individual regression coefficients was as follows :

Regression coefficient	Percentage average reduction
Linear	3
Quadratic	14
Cubic	7
Quartic	5
Fifth degree	6
Total .	35

In order to study the effect of fitting higher degree curves on the removal of variation, eighth degree polynomial curves were fitted by the summation method to the data for two seasons, 1928 and 1934. The percentage sum of squares accounted by the 8th degree curve in these two years was

Year	Percentage sum of squares accounted by 8th degree curve
1928	23·1
1934	46·6

Comparing these values with those given above for the corresponding fifth degree curves, it will be seen that although there was an improvement in both the seasons about 50 to 75 per cent variation was still left unaccounted for by the 8th degree curve. The percentage variation accounted by each regression coefficient for the 8th degree curves fitted to the data for the above two years are given below : –

Regression coefficient	Percentage reduction	
	1928	1934
Linear	2·6	2·8
Quadratic	4·4	13·6
Cubic	3·2	8·1
Quartic	1·9	3·3
Fifth degree	4·2	6·8
Sixth degree	0·5	1·1
Seventh degree	5·1	2·5
Eighth degree	1·2	8·4
Total .	23·1	46·6

From these results it would appear that higher degree polynomials than those of the fifth degree, besides being more complex, would not express the rainfall distribution much better to be useful for purposes of prediction.

Effect of group interval on the residual variation

The conclusions derived in the present investigation were based on fifth degree polynomial curves fitted to weekly rainfall totals. The division of the whole period of 365 days of each year into 52 weeks was arbitrary and the interval can be shortened or extended. Since the variation left for the residual component in the analysis of variance of each season was as high as 65 to 70 per cent, the relationship between the length of interval and the magnitude of the residual variation was examined, with a view to see whether the fit of the fifth degree polynomial could be improved by a change in the length of the interval. The daily rainfall values of some selected seasons were, therefore, grouped into 73 and 26 groups, each group consisting of 5 and 14 days respectively. Consequent to such a grouping the last group in the 5-day grouping consisted of 6 days in a leap year. With 14 days' grouping the last group of each year included 15 days except in the case of leap years in which it included 16 days.

In the following table are shown the comparative values of the percentage variation accounted for by fitting 5th degree polynomials to rainfall totals according to different grouping.

Percentage variation accounted by fitting fifth degree polynomial curve

Selected year	5 days grouping	7 days grouping	14 days grouping
1924	26·2	37·8	53·9
1926	30·4	42·3	51·2
1928	14·5	16·2	32·3
1930	20·8	32·8	45·6
1934	32·8	34·6	62·2
1944	36·1	45·2	59·1
1946	21·5	29·5	47·6

The results showed that when the group interval was increased, the percentage variation accounted for was also higher. The difference in the 7 and 14 days grouping was thus wider than between 5 and 7 days' grouping. This change in the closeness of the fit of the polynomial to the data by increasing the grouping interval

was to be expected, since wider interval itself smoothed the data by eliminating a portion of the variation in the original data.

(b) *The distribution and seasonal trends in the rainfall at Indore*

(1) *Variation in the rainfall constants.* It has been mentioned earlier that the six constants obtained by fitting a fifth degree curve to weekly rainfall totals of each season (Appendix B) varied from season to season. The extent of variation in these constants can be judged from the magnitudes of the standard deviations and coefficients of variation given in Table II.

TABLE II

Seasonal variability in rainfall constants

Statistic	Rainfall constants					
	A (Mean)	B (Linear)	C (Quadratic)	D (Cubic)	E Quartic)	F (Fifth degree)
Mean	0·761102	0·017863	—0·003028	—0·000155	$0{\cdot}995197\times10^{-5}$	$0{\cdot}854693\times10^{-6}$
S. E. of mean	0·032769	0·001340	0·000154	0·000010	$0{\cdot}86731\times10^{-6}$	$0{\cdot}78956\times10^{-7}$
S. D.	0·16053	0·006566	0·000754	0·000051	$0{\cdot}42489\times10^{-5}$	$0{\cdot}13868\times10^{-6}$
Coefficient of variation	21·1 per cent	36·7 per cent	24·9 per cent	32·7 per cent	42·7 per cent	45·3 per cent

The seasonal variation in all the six constants was large as seen from the high values of the coefficient of variation. The means of all the constants were also significantly different from zero which indicated that effects expressed by the constants were real and not random ones.

(2) *Average distribution of rainfall during 24 years.*—The equation of the fifth degree polynomial curve for the average distribution of rainfall values was obtained by substituting the mean values of each constant in the following equation :

$$Y=A+B\xi_1+C\xi_2+D\xi_3+E\xi_4+F\xi_5.$$

which after substitution can be written as

$$Y=10^{6}\,(761102+17863\xi_1+3028{\cdot}46\xi_2-154{\cdot}962\xi_3+9{\cdot}95197\xi_4+0{\cdot}854693\xi_5)$$

where, Y is the expected value of the average weekly rainfall for a given week.

This equation can be expressed in terms of time interval as follows :

$$Y=10^{-6}(-393716+330643\xi^1-62708{\cdot}46\xi^2+4162{\cdot}038\xi^3-3{\cdot}04803\xi^4+0{\cdot}854693\xi^5)$$ '(-' being the time interval of one week.

The expected values of rainfall during given intervals of time were calculated with the help of the above equation. The values thus obtained were further reduced to per day basis and are plotted in Fig. I. The average distribution of daily rainfall over the period of 24 years is given by the curve. A histogram of the average rainfall per day calculated from actual monthly totals is also shown in the same figure. It will be seen that the curve fitted reasonably well to the smoothened data by taking the monthly averages shown in the histogram. When, however, the curve is superposed on a histogram of actual weekly totals from which it was derived, it showed a

FITTED TO WEEKLY RAINFALL

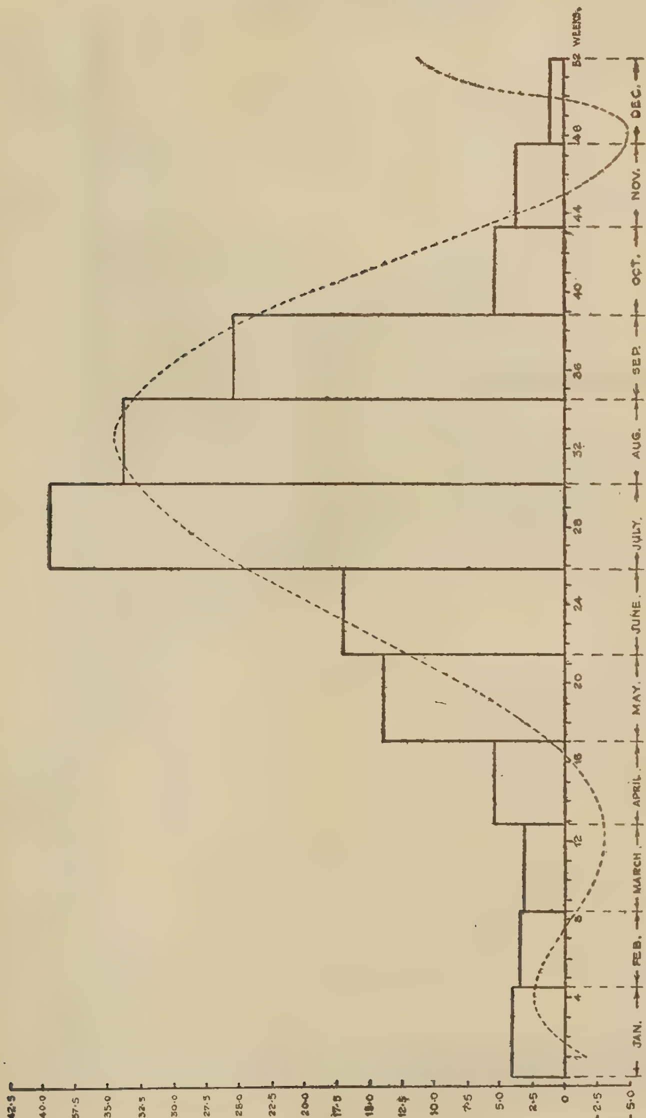


Fig. 1.—Monthly distribution of average daily rainfall and the fifth degree polynomial rainfall in cents

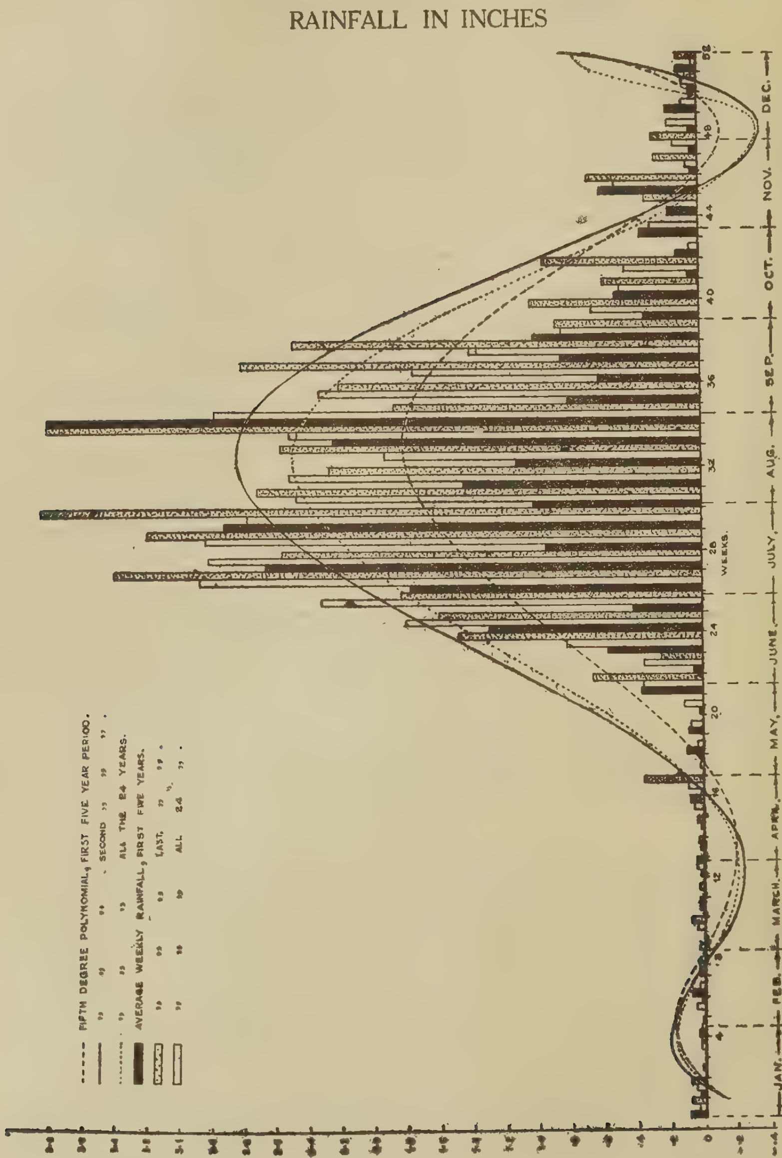


Fig. 2.—Average distribution of weekly rainfall and corresponding fifth degree polynomials

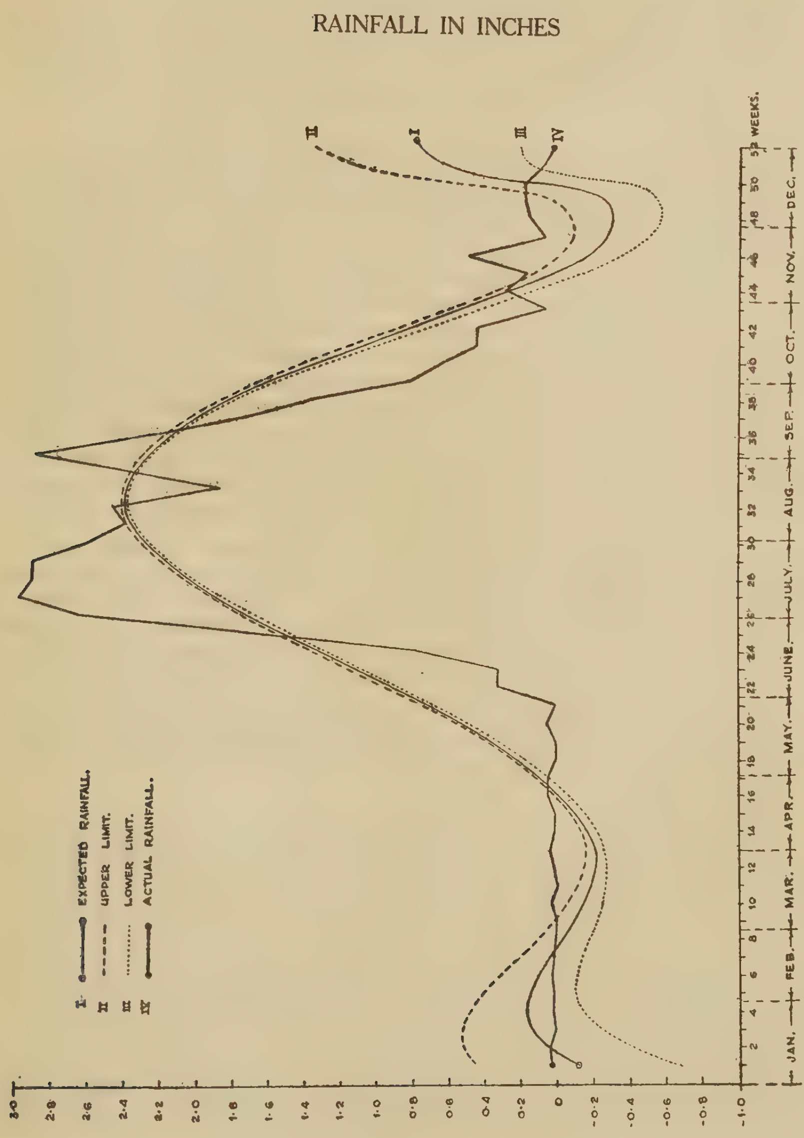


FIG. 3. Average distribution of weekly rainfall and corresponding Fifth degree polynomial with upper and lower limits

much poorer fit (Fig. 2). From the distribution shown by the curve, it can be said that a bulk of the rainfall was received during four months from June to September. The high and significant values of the linear and quadratic coefficients, B and C, given in Table II indicated that there was a sudden increase in the average weekly rainfall instead of a gradual one, and after attaining the maximum value, it again declined rapidly.

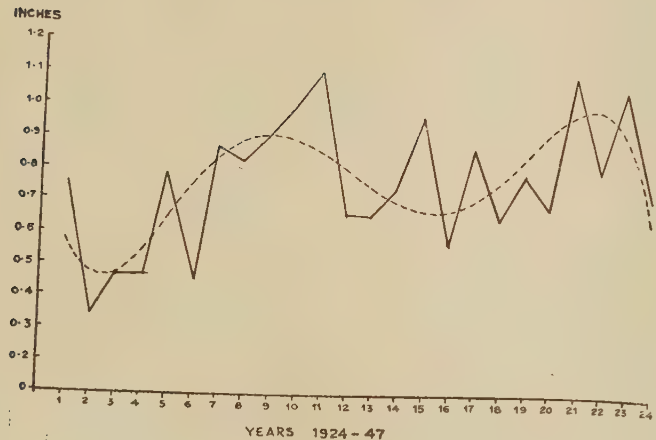
A reference to the histogram of weekly rainfall shown by blank columns for the whole period of 24 years in Fig. 2 reveals that the rainfall distribution was of a bi-modal nature. This point is seen even more clearly in the polygon shown in Fig. 3. The weekly rainfall increased and reached a maximum value by the end of July and then decreased up to middle of August, whereafter it again increased up to the first week of September when it reached a second maximum and finally declined at a rapid rate. The decrease in rainfall in the month of August and its further increase in the month of September might be due to the effect of the two monsoons, South-West and North-East. The South-West monsoon, which starts at Indore by the middle of June, was responsible for the precipitation up to the end of July after which its intensity retarded. The North-East monsoon started at about the same time and effected an increase in the weekly rainfall up to the middle of September after which its influence was lessened. If, as it appears, the distribution of rainfall reflects the joint effect of the two monsoons, this fact would provide a partial explanation of the relatively poor fit of a smooth polynomial curve to the data.

(3) *Slow changes in the rainfall constants.* Since the seasonal variation in the rainfall constants was high as demonstrated by the large values of the coefficients of variation given earlier, the nature of this variation was examined in order to find out whether it was systematic or purely random. Polynomial curves of the fifth degree were again fitted to the 24 values of each of the six coefficients separately. The analysis of variance for the polynomial for each constant is given in Table III.

It will be seen from Table III that collective variances as well as the linear and fifth degree components were significant in the case of constants A and C. With regard to the other four constants, only the fifth degree component for constants B and D was significant.

The linear component for constant A was positive and its value was 0·012 which indicated that the average weekly rainfall increased significantly at the rate of 1·2 cents per week per year. The linear component of constant C was negative and had a value of —0·00006. The change in constant C reflected changes in the curvature of the parabola for the average distribution. The significant negative value of the linear component of this constant indicated that the rate of decrease of average rainfall after attaining the maximum value had increased with the passage of time. The aggregate change brought about in the distribution of rainfall was to increase the steepness of the distribution curve while keeping the period receiving the bulk of the rainfall constant. The significant values of the fifth degree component of all the constants, except for the last two, showed that the changes in the distribution were of a periodic character. A reference to the distribution curves of the constants A and C (Fig. 4*a* and 4*b*) indicates a periodic cycle of 7 years.

Fig. 4 *a*.



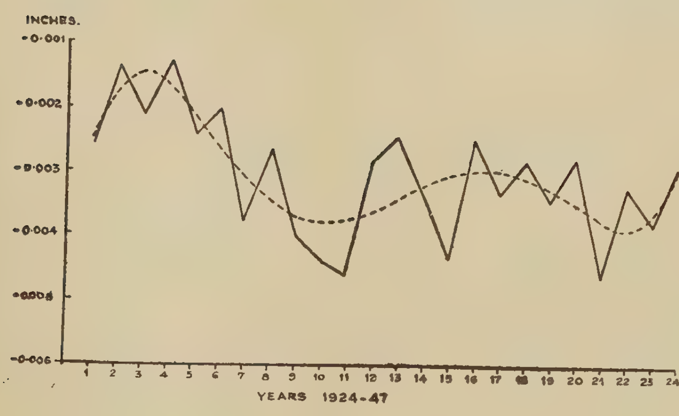


Fig. 4 *b*.

FIG. 4 *a*. Progressive changes weekly rainfall.

FIG. 4 *b*. Progressive changes in coefficient 'G' of the annual rainfall Polynomial

TABLE III

Analysis variance of fifth degree polynomial curves fitted to six rainfall constants

Variation due to	D.F.	Mean squares					
		A	B	C	D	E	F
Linear	1	0·179915*	$0{\cdot}216044 \times 10^{-8}$	$0{\cdot}421107 \times 10^{-5}$	$0{\cdot}317540 \times 10^{-8}$	$0{\cdot}739930 \times 10^{-10}$	$0{\cdot}138970 \times 10^{-11}$
Quadratic	1	0·047574	$0{\cdot}635019 \times 10^{-7}$	$0{\cdot}207954 \times 10^{-5}$	$0{\cdot}349600 \times 10^{-10}$	$0{\cdot}326830 \times 10^{-10}$	$0{\cdot}202000 \times 10^{-13}$
Cubic	1	0·029517	$0{\cdot}881354 \times 10^{-4}$	$0{\cdot}243810 \times 10^{-6}$	$0{\cdot}283762 \times 10^{-8}$	$0{\cdot}161900 \times 10^{-12}$	$0{\cdot}668600 \times 10^{-13}$
Quartic	1	0·021640	$0{\cdot}219897 \times 10^{-4}$	$0{\cdot}331710 \times 10^{-6}$	$0{\cdot}760200 \times 10^{-10}$	$0{\cdot}539800 \times 10^{-12}$	$0{\cdot}274000 \times 10^{-15}$
Fifth degree	1	0·248300**	$0{\cdot}185273 \times 10^{-3}$*	$0{\cdot}383414 \times 10^{-5}$**	$0{\cdot}271793 \times 10^{-7}$	$0{\cdot}149480 \times 10^{-10}$	$0{\cdot}439670 \times 10^{-12}$
Collective for all coefficients	5	0·104010*	$0{\cdot}591356 \times 10^{-4}$	$0{\cdot}214005 \times 10^{-5}$	$0{\cdot}666465 \times 10^{-6}$	$0{\cdot}244650 \times 10^{-10}$	$0{\cdot}133194 \times 10^{-12}$
Residual	18	0·025778	$0{\cdot}354540 \times 10^{-4}$	$0{\cdot}568185 \times 10^{-7}$	$0{\cdot}256844 \times 10^{-8}$	$0{\cdot}180529 \times 10^{-10}$	$0{\cdot}149673 \times 10^{-12}$

*Significant on 5 per cent level
**Significant on 1 per cent level

The fact that the average weekly rainfall had a tendency to increase steadily could be demonstrated by comparing the average annual rainfall during different periods. For this purpose the whole period of 24 years was divided into 5 groups of 5 years except that the last one included only four years. The average annual rainfall in inches for each group is given below :

Years	Average annual rainfall (inches)
1924—1928	29·41
1929—1933	42·02
1934—1938	43·02
1939—1943	37·11
1944—1947	48·02

These averages indicate the increasing tendency of the average rainfall, apart from the effect of the periodic trend.

It has been mentioned above that the increase in the average rainfall was not due to the extension of the span of rainfall period but due to a higher precipitation during the main rainfall period which commenced from the middle of June and ended by the end of September. This fact was brought out clearly by comparing the average distribution for the two end periods viz. 1924—1928 and 1943 to 1947. In the following table is given the analysis of variance of the fifth degree curves fitted separately to the two periods. The significance of the difference in the mean values of each component of the curves is also shown in Table IV.

TABLE IV

Comparison of the average rainfall per week during two end periods and the significance of the respective constants

Constants	I 1924—1928		II 1943—1947		S. E. of diff.	ε
	Mean	S. E.	Mean	S. E.		
A	0·565577	0·088152	0·874231	0·087108	0·123930	2·50*
B	0·016396	0·003452	0·020926	0·002468	0·004244	1·07
C	—0·001948	0·000261	—0·003440	0·000341	0·000429	3·47*
D	$-0{\cdot}124203\times10^{-3}$	$0{\cdot}284835\times10^{-4}$	$-0{\cdot}182780\times10^{-3}$	$0{\cdot}291427\times10^{-4}$	$0{\cdot}407505\times10^{-4}$	1·44
E	$0{\cdot}610598\times10^{-4}$	$0{\cdot}106598\times10^{-5}$	$0{\cdot}108645\times10^{-4}$	$0{\cdot}192754\times10^{-5}$	$0{\cdot}220266\times10^{-5}$	2·16
F	$0{\cdot}674997\times10^{-6}$	$0{\cdot}158264\times10^{-6}$	$0{\cdot}9575400\times10^{-6}$	$0{\cdot}226250\times10^{-6}$	$0{\cdot}276110\times10^{-6}$	1·02

*Significant on 5 per cent level

Comparison of the mean values for constant A in the two periods showed that the average weekly rainfall in the second period (1943—1947) was significantly higher than in the first (1924—1928) period. Similarly the significant difference in the mean values of constant C indicated that the distribution in the second period was steeper than that in the first period.

These points have been well illustrated in Fig. 2. The top curve representing the distribution of the average weekly rainfall received during the last five years has a distinctly greater slope as compared to the curve for the first five years. It will also be observed that the span of the main rainfall period had remained unchanged.

(4) *Comparison of distribution of rainfall recorded at different centres.* In the previous section the results obtained from a study of the rainfall measured at the Institute have been discussed. As mentioned in the beginning, two other sets of figures, one from K. E. M. Hospital and the other from the office of the Director of Land Records were examined for comparison of the rainfall at these gauges with that recorded at the Institute.

The annual rainfall recorded at the three gauges are given in Appendix C. An analysis of variance of these data are shown below :

TABLE V

Analysis of variance of annual rainfall recorded at three centres during 24 years (1924—1947)

Variation due to	D. F.	Mean square
Years	23	357·23
Places	2	9·48**
Years X places (error)	46	2·77

**Significant on 1 per cent level

It is interesting to note that the variation due to places which, as stated earlier are within a distance of not more than two miles from one another was significant. The mean rainfall at the three centres for the period of 24 years with their standard errors are given below :

Place	Average annual rainfall (inches)
K. E. M. Hospital	40·74
D. L. R.'s Office	39·75
Institute of Plant Industry	39·58
S. E.	0·34
Significant difference	0·97

Rainfall recorded at the K. E. M. Hospital was significantly higher than that recorded at the other two places.

To study the seasonal trend in the rainfall recorded at these two places, a fifth degree polynomial was fitted to the average weekly rainfall per year for each centre. The analysis of the polynomials thus fitted is given below:

TABLE VI

Analysis of variance of fifth degree polynomial curves fitted to average weekly rainfall recorded at K. E. M. Hospital and D. L. R.'s Office

Variation due to	D. F.	Mean squares	
		K. E. M. Hospital	D. L. R.'s Office
Linear	1	0·1926*	0·2252*
Quadratic	1	0·0320	0·0375
Cubic	1	0·0288	0·0358
Quartic	1	0·0098	0·0087
I ifth degree	1	0·2057*	0·1688*
Resid 1	18	0·0347	0·0304

* Significant on 5 per cent level

The mean squares for all components, except the quartic, for both curves were nearly of the same magnitude as those for the curve fitted to the Institute data and shown under constant A in Table III. Only the linear and fifth degree regression coefficients were significant in the above analysis for both the centres as was observed in the case of the curve for the Institute data. The distribution curves of the rainfall averages for both places were practically identical in shape to the one given for the Institute in Fig. 4*a*.

(5) *Prediction of rainfall.* The average distribution of weekly rainfall during the period of 24 years was given by the equation of the fifth degree polynomial curve referred to in section (2). With the help of this equation the expected value of the rainfall during any interval of time can be calculated. These expected values are influenced by the variability of the coefficients of the polynomial. In order to determine the range of fluctuation in the expected values in either direction, or in

other words, in order to determine the fiducial limits of predicted values, the standard error of each of the expected values for a given time interval ε was calculated from the formula [Fisher, 1946].

$$\text{S.E. of } \gamma=\sigma^2 \sqrt{\left(\frac{1}{n}+\frac{(t-\bar{t})^2}{\varepsilon\,(t-\bar{t})^2}+\ldots\ldots\right)}$$

Where σ^2 for the polynomial of the rth degree fitted to n values can be expressed as

$$\sigma^2=\frac{1}{n-r-1}\left\{s(y^2-nA^2-)\frac{n(n^2-1)}{12}B^2-\ldots\ldots\right\}$$

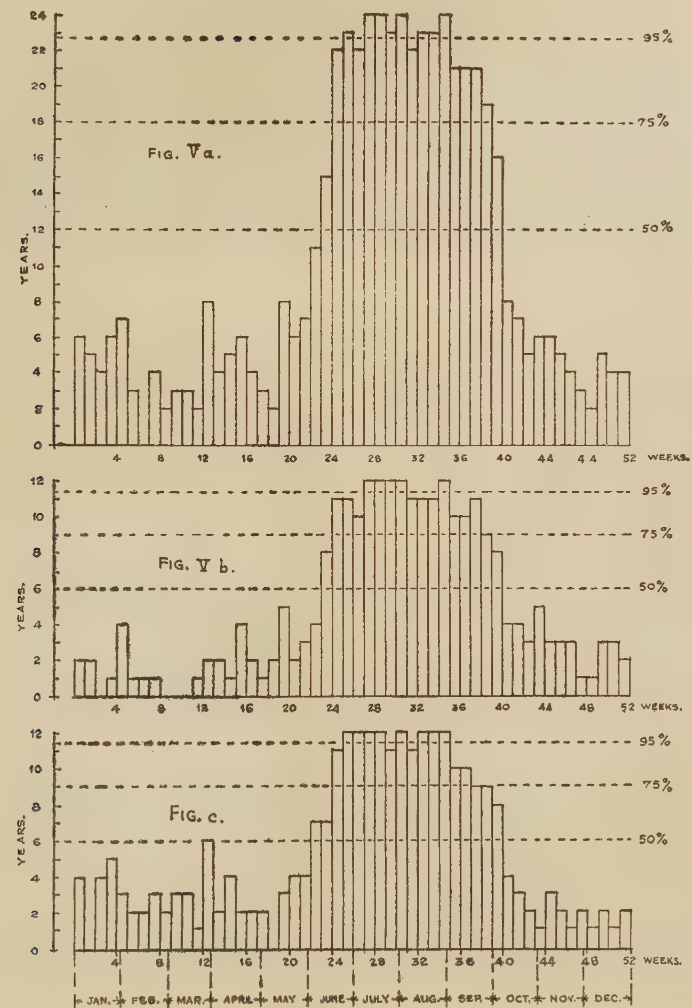
The fiducial limits of any expected value Y will be equal to $\Upsilon \pm 2$S.E. In Appendix D are given the expected values of average weekly rainfall with their upper and lower limits calculated by the above method. Wherever the values are negative they have to be interpreted as indicating absence of rainfall. The curve for the expected values of the average weekly rainfall with its upper and lower limits is shown in Fig. 3 against a polygon representing the actual distribution of weekly rainfall. An examination of these curves would make it clear that the limits of the expected values were very narrow from about 16th week up to 43rd week, i.e. from the middle of May to middle of October which is the main period of rainfall in the season. The limits of the two end periods were wide which was to be expected, since the seasonal variation in the rainfall received in these periods was much greater as compared to the central period. The prediction of the amount of rainfall during the weeks included in the central period would have a high degree of precision, assuming that the distribution represented by the polynomial had remained constant. Since, however, a significant trend has been revealed in the annual distribution, the value of any prediction based on the average distribution is much diminished.

(8) *Frequency of occurrence of rainfall in each week.* Apart from the quantity of rainfall received in any week, information on the probability of occurrence of rainfall within a particular week is equal interesting. The number of years out of the total of 24 years, in which there was rain in a given week were counted. Fig. 5*a* shows the frequency of seasons in which there was rainfall in each week.

It is interesting to note that in 4 weeks (28, 29, 31 and 35) rainfall occurred in all 24 seasons. In the 1st to 23rd weeks and 41st to 52nd weeks rainfall occurred in less than half the number of years.

The proportion of seasons in which rainfall occurred in a particular week is indicated in the figure. This proportion may be regarded as indicating the independent probability of precipitation in a given week assuming, of course, that the rainfall distribution is unaltered. It would be more interesting to calculate probabilities of occurrence of rainfall in a given week on the basis of knowledge already available regarding the actual occurrence or otherwise of rainfall during the preceding weeks.

Since it has been demonstrated earlier that the annual distribution of rainfall has undergone a steady change over the period of study, it was thought interesting to split the period into two halves of 12 years each, and record the frequency of



FREQUENCY OF OCCURRENCE OF WEEKLY RAINFALL

Fig. 5 (*a*) During Whole Period 1924—1947.

Fig. 5 (*b*) ,, First Half 1924—1935.

Fig. 5 (*c*) ,, Second ,, 1936—1945.

occurrence of weekly rainfall in each half separately. A graph of these frequencies is shown in Fig. 5 *b—c*. Although the two sets of frequencies are broadly similar, certain changes are apparent from the graphs. The principal difference is that the frequency of weekly rainfall has increased in the central part of the rainy season of 21st to 39th weeks during the second 12-year period as compared to the first. Similarly the frequency of occurrence in the first five months of the year has also shown a definite increase during this latter period while the frequency of rainfall during one and a half month at the end of the year has shown a decrease. This means a shift in the period of winter rainfall from December to January and February as also a slight increase in the frequency of summer showers. These changes are part of the changes in the general distribution of rainfall which have been discussed earlier.

Summary

The distribution and seasonal variability of the weekly rainfall received during the period of 24 years from 1924 to 1947 at the Institute of Plant Industry, Indore, was studied by fitting polynomial curves of the fifth degree.

Fitting of 8th degree curves to the data was tried in selected years but did not show appreciable improvement over the fifth degree curves. Examination of the effect of group interval on the fit of the fifth degree curve showed that the fit was better when the group interval was longer.

The distribution study showed that (1) the average weekly rainfall had a tendency to increase, (2) this tendency was not due to the increase in the period of rainfall but due to a higher precipitation in the rainfall period from middle of June to end of September, (3) there seemed to be operating a cycle of 7 years period, in the distribution of the average rainfall, (4) the distribution diagram was bi-modal, the first and second peaks being observed at the beginning of July and end of August respectively. The bi-modal distribution might be due to the effect of two monsoons, *viz.*, South-West and North-East.

The fiducial limits of the expected values obtained from the fifth degree polynomials fitted to weekly values of rainfall, were worked out and showed a very narrow range during the period in which a bulk of the total rainfall was received. The prediction of the quantity of rainfall received during this period would, therefore, have a high degree of precision.

A study of the rainfall records obtained from the K. E. M. Hospital and Director of Land Record's Office showed the same distribution as was observed in the case of Institute, but the average annual rainfall recorded at the K. E. M. Hospital was significantly higher than that recorded at the other two places.

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Appendix A

Weekly rainfall in inches recorded at the Institute of Plant Industry, Indore, 1924—1947

Month	Week	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
January	1	0·45										0·03	
	2	0·08											0·15
	3												
	4												0·01
February	5					0·16		0·06	0·06			0·03	
	6						0·75						
	7					0·37							
	8				0·09								
	9												
March	10												
	11												
	12									0·44			
	13	0·05								0·04			
April	14	0·02					0·06						
	15						0·13						
	16							0·03			0·02	0·04	0·92
	17						0·02						0·14
May	18		0·03										
	19		0·44								0·01		
	20	0·35				0·01		0·02			0·57		0·45
	21	0·06						0·23					
	22	0·65	1·11						0·15				
June	23		0·24				0·33	0·50		0·10			
	24	1·02			1·17	0·58		0·30	1·36		0·18	1·51	1·70
	25	0·52	3·05	0·55	1·23	1·02	2·00	2·79		0·38	8·84	1·10	0·27
	26	0·05	0·88		0·21	0·74	2·18	2·66	0·98	3·01	1·07	8·12	4·00
July	27	1·43		3·43	1·82	1·95	1·18	4·62	2·28	2·11		4·82	3·62
	28	3·73	1·02	3·50	1·75	2·89	4·12	3·30	1·36	5·02	2·67	1·25	1·65
	29	0·16	0·44	0·35	1·33	2·23	2·10	2·82	5·76	13·18	8·96	0·33	5·56
	30	4·16	1·28	0·76	1·35	6·44	0·87	4·50	1·22	2·72	2·00	0·60	0·54
August	31	1·45	1·09	1·53	0·42	0·45	0·37	2·70	3·34	1·65	6·79	5·59	2·35
	32	1·47	1·94	2·11	1·46	0·08		3·72	1·70	1·60	4·41	2·41	1·05
	33		1·65	1·92	1·42	0·51	0·34	0·05	2·93	0·48	0·24	13·50	0·69
	34	2·05	0·35	5·45	0·42	2·90	4·59		4·16	0·25	2·38	0·62	0·06
	35	8·97	2·06	2·44	3·10	14·07	3·05	1·18	1·71	0·22	1·74	0·26	2·61
September	36	2·87		0·08	0·38	0·70	1·15	1·40	0·44	9·90		4·63	0·64
	37	0·24		1·98	0·84	0·01	0·17	11·46	0·04		9·08	5·21	5·20
	38	2·89	0·23	0·10	0·01	0·87		1·88	2·00	3·25	1·25	1·19	0·86
	39	2·74	0·21	0·11	1·73	0·09		0·27	2·67	0·14		4·80	
October	40	0·37			1·11	0·15		0·04	3·32	1·22	0·23		0·47
	41	2·50						0·02	2·65	0·84			
	42	0·28							0·80	0·39	0·68		
	43				0·01	0·62							0·36
November	44				1·74			0·58	3·12			0·03	1·03
	45		0·90		0·01							1·37	
	46		0·80		2·10	0·01							
	47		0·09			0·02					0·19		
	48					0·09							
December	49					4·22							
	50	0·92							0·78				0·02
	51			0·16							0·51	0·02	
	52				0·61							0·05	
Total		39·48	17·81	24·47	24·31	40·98	23·41	45·13	42·83	46·94	51·82	57·51	34·35

Appendix A—*contd.*

Weekly rainfall in inches recorded at the Institute of Plant Industry Indore, 1924—1947

Month	Week	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
January	1			0·01					0·03	0·22	0·16		
	2						0·41		0·20		0·21		
	3					0·11	0·06	0·31			0·11		
	4				0·04	0·06		0·42	0·06				0·02
February	5		0·07			0·11			0·03				
	6		0·01										0·04
	7	0·10	0·03										
	8	0·02					0·27					0·01	
	9						0·07	0·23					
March	10	0·11				0·18				0·37			
	11				0·15	0·03				0·04			
	12									0·02			
	13	0·50	0·10	0·12	0·01					0·18			0·03
April	14	0·12											0·11
	15		0·04				0·03		0·15			0·01	
	16					0·03							0·34
	17					0·03					1·67		
May	18					0·02			0·07				
	19												
	20							0·01				0·04	0·08
	21	1·38		0·12		0·63						0·12	
	22	0·03		2·88	0·24				3·20				
June	23			4·63	1·03	0·19			0·13	0·02		0·51	0·53
	24		0·44	3·79				0·35	2·21	2·10	0·44	1·91	
	25	1·90	2·92	3·88	0·54	1·66		1·32	2·70	0·35	1·82	2·90	0·53
	26	6·01	5·07	0·28	0·13	6·19	2·95	1·12	0·17	0·18	1·38	6·68	0·32
July	27	0·36	0·72	2·42	3·80	2·15	6·90	6·68	0·98	2·42	2·77	10·92	4·17
	28	0·18	3·07	9·16	4·69	5·77	1·49	2·48	2·89	1·67	3·68	0·04	2·61
	29	0·45	2·32	1·21	0·12	3·60	0·07	3·83	1·80	8·80	1·74	1·38	1·37
	30	1·35	7·97	4·46	0·12	2·89		1·56	4·04	4·68	4·28	5·17	0·81
August	31	2·56	0·85	0·09	0·02	3·51	0·21	9·82	0·72	6·36	0·10	5·08	0·30
	32	0·83	3·36	4·73		0·73	11·18	0·81	0·43	6·30	1·55	2·46	4·52
	33	0·89	0·15	1·19	1·43	3·18	2·52	0·30	0·27	1·74	3·41	2·57	3·52
	34	0·32	0·91	1·07	5·36	3·48	1·87	0·51	2·93	10·70	2·33	2·77	2·09
	35	0·58	0·16	1·21	8·34	0·55	0·06	5·46	4·91	0·40	1·49	0·29	4·28
September	36	7·63	8·10	0·40	1·91		0·13	0·83	0·39	0·20	5·32	0·60	6·98
	37	1·89	1·13	1·31	0·18	0·25	2·82	3·15	-0·34	3·62	1·13	1·65	
	38	0·15			1·42	3·16	2·46	1·21	4·18	1·43	6·39	0·04	1·73
	39	1·13	0·23	0·59		0·80	0·63		0·02	0·27	1·74	0·47	1·11
October	40		0·32	2·74	0·02				0·14	2·77	0·10	0·84	1·62
	41			4·02						0·33	0·23	0·72	
						3·88			2·55	2·07			
	42								2·55				
	43		0·47			0·06							
November	44				0·39								
	45	0·23		0·01								1·64	
	46	5·57										3·28	
	47											1·27	
	48					1·99						1·34	
December	49											0·05	
	50		0·11									0·09	
	51				—	—		0·28					0·34
	52		0·10									0·48	
Total		34·29	38·65	50·32	29·94	45·24	34·13	40·68	35·54	57·24	42·05	55·33	37·45

APPENDIX B

Values of different constants for the fifth degree orthogonal polynomial

Constant	A	$B\times10^1$	$C\times10^2$	$D\times10^3$	$E\times10^5$	$F\times10^6$
1924	·759231	0·229429	—·253305	—·210646	·524675	·974917
25	·342500	·067024	—·137515	—·045504	·508400	·177424
26	·470577	·111205	—·212473	—·117287	·771117	·819526
27	·467500	·162345	—·128554	—·088354	·321664	·366612
28	·788077	·249816	—·242349	—·159224	·927133	1·066505
29	·450192	·058862	—·202252	—·080902	·816796	·594172
30	·867212	·197620	—·374727	—·195509	1·164138	1·011167
31	·823654	·285725	—·260258	—·211267	·347293	·780748
32	·902673	·198604	—·397178	—·202270	1·326768	1·206610
33	·996462	·208234	—·438203	—·193519	1·663545	1·326230
34	1·105865	·280741	—·457957	—·268049	1·313400	1·451103
35	·660577	·119888	—·279630	—·114467	·947324	·557160
36	·659423	·196862	—·196036	—·113386	·302891	·256455
37	·743269	·142496	—·337379	—·144363	1·327036	·936500
38	·967692	·136011	—·432005	—·112095	1·614569	·530895
39	·575769	·140587	—·245949	—·080877	·688489	·934607
40	·870000	·198719	—·331290	—·148298	1·208850	·659612
41	·656346	·125267	—·283618	—·155084	1·063980	·967385
42	·782308	·136959	—·343553	—·164072	1·614417	1·137306
43	·683462	·134082	—·275931	—·128777	·804844	·521512
44	1·100769	·267506	—·461423	—·282452	1·418574	1·669432
45	·808654	·185900	—·319478	—·188710	·787604	1·031086
46	1·064038	·259280	—·375707	—·119775	1·717227	·421990
47	·720192	·199552	—·287533	—·194188	0·704000	1·143682
Mean	·761102	·178863	—·302846	—·154962	·995197	·854693

Appendix C

Annual rainfall (inches) recorded at three places at Indore

Year	Institute Farm	D. L. R.'s Office	K. E. M. Hospital
1924	39·48	35·23	39·59
1925	17·81	19·95	19·93
1926	24·47	22·98	23·91
1927	24·32	27·99	29·38
1928	41·18	43·10	43·09
1929	23·41	23·65	25·34
1930	45·13	45·21	49·35
1931	42·83	39·84	39·62
1932	46·94	42·42	42·90
1933	51·51	51·65	53·35
1934	57·50	57·32	57·66
1935	34·35	35·34	37·05
1936	34·29	36·20	34·14
1937	38·65	37·17	38·01
1938	50·32	49·06	52·40
1939	29·94	31·84	32·20
1940	45·24	46·82	47·81
1941	34·13	33·20	33·98
1942	40·68	39·40	39·46
1943	35·54	37·24	37·78
1944	57·24	63·95	63·24
1945	42·05	37·58	39·04
1946	55·33	56·98	60·51
1947	37·45	39·92	38·08

Appendix D

Expected values of average weekly rainfall (inches) with upper and lower limits

Month	Week	Expected rainfall	Upper limit	Lower limit
	1	—0·12	0·45	—0·69
	2	0·05	0·53	—0·42
January	3	0·14	0·52	—0·24
	4	0·17	0·49	—0·15
	5	0·15	0·42	—0·11
	6	0·10	0·32	—0·11
	7	0 34	0·21	—0·13
February	8	—0·03	0·11	—0·17
	9	—0·10	0·02	—0·21
	10	—0·15	—0·06	—0·24
	11	—0·19	—0·12	—0·26
March	12	—0·21	—0·15	—0·27
	13	—0·20	—0·16	—0·25
	14	—0·17	—0·13	—0·21
	15	—0·11	—0·08	—0·14
April	16	—0·02	0·03	—0·05
	17	0·09	0·11	0·07
	18	0·23	0·24	0·21
	19	0·39	0·40	0·37
	20	0·55	0·56	0·54
May	21	0·75	0·76	0·74
	22	0·95	0·96	0·94
	23	1·15	1·16	1·14
	24	1·36	1·36	1·35
June	25	1·55	1·56	1·55
	26	1·74	1·75	1·74

APPENDIX D—*contd.*

Expected values of average weekly rainfall (inches) with upper and lower limits

Month	Week	Expected rainfall	Upper limit	Lower limit
	27	1·92	1·92	1·91
	28	2·07	2·08	2·06
July	29	2·20	2·20	2·19
	30	2·30	2·31	2·29
	31	2·37	2·38	2·36
	32	2·40	2·41	2·39
	33	2·38	2·40	2·37
August	34	2·35	2·36	2·34
	35	2·27	2·29	2·25
	36	2·15	2·17	2·13
	37	1·99	2·02	1·96
September	38	1·80	1·83	1·77
	39	1·57	1·62	1·53
	40	1·32	1·37	1·28
	41	1·06	1·12	1·00
October	42	0·78	0·86	0·71
	43	0·51	0·60	0·42
	44	0·24	0·36	0·13
	45	0·01	0·15	—0·13
	46	—0·18	—0·01	—0·35
November	47	—0·31	—0·09	—0·52
	48	—0·36	—0·09	—0·62
	49	—0·30	0·02	—0·62
	50	0·11	0·49	—0·26
December	51	0·64	1·11	0·16
	52	0·77	1·34	0·20

REVIEWS

By P. Maheshwari

AN INTRODUCTION TO THE EMBRYOLOGY OF ANGIOSPERMS

(*Published by McGraw-Hill Book Company, Inc. New York, Toronto and London, $ 6·00*)

ALTHOUGH comprehensive text books have been available in the German Language, no authoritative account of the embryology of angiosperms has appeared in the English language since the publication in 1903 of Coulter and Chamberlain's *Morphology of Angiosperms.* During the half century that has elapsed since then, great advances have been made in the subject and Coulter and Chamberlains's book has been for a long time both out-of-date and out-of-print. This big gap in the literature on the morphology of angiosperms, which has handicapped both the teachers and the students in the study of the subject, has been bridged now most successfully by Professor Maheshwari.

The new book gives an account of the structure and development of the pollen, ovule, embryo-sac, the process of fertilization, development of the endosperm and embryo of flowering plants. It is carefully planned and presents a scholarly synthesis of the present knowledge. The account is clear and confined to the fundamentals of the subject, so that even the undergraduate student and the non-specialist can easily follow it, but for those who may like to go deeper or intend to take to original investigations in this field, there are ample references at the end of each chapter to guide them to authoritative literature on the subject.

An evidence of the author's mastery of the subject may be mentioned the fact that there is hardly any passage in the whole book with which anyone can positively disagree. He has assembled and digested an enormous number of papers published on the subject and the book contains few statements on which anyone can comment.

Dealing with the male gametophyte, we find on page 154 : ' The microspore, which is the first cell of the gametophyte generation, undergoes only two divisions. The first division gives rise to a large vegetative cell and a small generative cell. The second, which concerns only the generative cell, may take place either in the pollen grain or in the pollen-tube and gives rise to the two male gametes '. This can imply that the first division always takes place in the pollen grain before it is shed and the pollen grains are shed either in the 2-nucleate or 3-nucleate stage. The statement does not cover the case of those angiosperms where the pollen grains are shed in the 1-nucleate condition and the first nuclear division takes place after pollination.

Under megasporogenesis, the fact, that in *Iphigenia* all the four megaspores of the tetrad as a rule develop up to the 2-nucleate stage, deserves mention.

Professor Maheswari does not attach much phylogenetic importance to the phenomenon of chalazogamy. He regards it to be only of physiological significance.

This explains the occurrence of this mode of fertilization in several unrelated plants, but does not explain its presence in many members of the Amentiferae. In the same connection it is stated that in *Boerhaavia*, although the pollen-tube actually enters through the microphyle, it first makes a horizonal crossing through the funiculus. This is doubtful. The pollen-tube perh aps passes only through an obturator consisting of a tuft of hair arising from the base of the funiculus.

On p. 298, in the heading 'Unclassified or abnormal embryos', the use of the work 'abnormal' does not appear to be quite appropriate. It would be perhaps better to avoid this expression, for these types of embrogenies are just as normal for these plants as the *Capsella* type is for most crucifers. If a substitute for the expression 'Unclassified types' has to be found, 'Other types' would perhaps better convey the meaning.

Chapter 11 deals with embryology in relation to taxonomy. Here it is shown, how evidence from embryology could be utilized in clearing up the phylogenetic relationships of familes and genera of doubtful affinities. The author first gives a list of embryological features which he considers to be of 'major value' in the solution of taxonomic problems. To these it would be desirable to add the presence or absence of starch grains in the fertilizable embryo-sac. This character is constant in certain groups. It has been found, for instance, useful along with other features in separating *Molluginaceae* from *Aizoaceae*. The author next shows how embryological evidence has been utilized in establishng the true (?) relationships of *Empetraceae*, *Lennoaceae*, *Cactaceae*, *Garryaceae*, *Trapa*, *Callitrichaceae*, and the inter-relationships of the various tribes of *Liliaceae*.

Of special interest to agricultural workers should be the chapter on experimental embryology. Here the author summarises recent studies bearing on the experimental control of fertilization, including the storage of pollen, breaking of barriers to crossability among related plants, artificial culture of embryo, induction of parthenogenesis by exposure to high or very low temperature, use of X-rayed or foreign pollen, delayed pollination and chemical treatments, production of aventive embryos and induction of parthenocarpy by various agencies. The geneticist and plant breeder is shown in this chapter new tools, which can be of immense help to him.

The last chapter deals with certain theoretical problems connected with the homologies of the male gametophyte, embryo-sac, endosperm a nd embryo. There is, of course, no difficulty in recognizing the male gametophyte of angiosperms as a reduced and simplified form derived from some ancestral gymnosperm, but the homologies of the embryo-sac are even now not clear and have aroused considerable controversy. The author briefly explains the three theories that have been put forward in this connection and rightly concludes that the Gnetalean theory, which considers all the cells of the embryo-sac as potential eggs, is the one least open to objection. This, however, in no way implies any direct derivation of the angiosperms from the Gnetales.

The book is profusely illustrated and like all McGraw-Hill publications is neatly printed on high quality paper. Still a few spelling mistakes (due mostly to mechanical slips) have crept in. *Anona* (p. 30) is now written as *Annona*. This is correctly

spelt on p. 256. On p. 87, paragraph 3, in the sentence 'Even when........sections', the verb is missing. On p. 97, the last two lines, the meaning of 'Their origin is .....stage' is not quite clear. On p. 175, the phrase 'Exine end of the pollen grain' is ambiguous. It is hoped that these minor errors will be attended to in the next edition.

The subject of the embryology of engiosperms has been gaining popularity in this country during the last 25 years. Clearly, this is a book that will help in the study of this subject and stimulate further research. (A.C.J.)

THE GARDEN IN THE PLAINS

EDITED BY A. W. HARLER

(*Published by the Oxford University Press, Madras, 3rd Edition, 1948, 412, Rs. 13*)

THE fact that the third edition of this book has been brought out now since it was first published in 1941, shows the popularity which it enjoys among the various orchard loving people in India. This book is written to convey the various phases of horticulature to the common man in India in a very simple form. It is written in a simple, non-technical language and can be easily understood by a layman with profit and pleasure. It gives many practical hints to gardeners which can be easily applied on the fields. Characters of various flowers, shrubs, ferns, trees, fruits and vegetables have been fully described to identify one from the other. The new features of this revised edition are the sections dealing with laterite soils, growth promoting substances, modern insecticides, art of flower arrangement and birds in the garden.

The author has selected common plants giving all the possible scientific and common names to them and has avoided confusing the readers with huge list of plants. This book should find its utility with every garden lover in India. This book will meet the requirements of amateur gardeners in India and those who are looking forward to step into the gardening line. It thus takes the middle path between the idle chats and a serious technical type of book. To Scientists, it is helpful to clear many of doubts regarding the terminology of various plants found in India and the gardening practices in vogue.

The book is divided into six parts ; the garden in general ; gardening operations ; trees, shrubs and permanent garden features ; flowers ; vegetables and fruits ; miscellaneous. The first four parts which deal with ornamental horticulture cover more than 3/4th of the book and deal with general gardening, soil and manuring, plant propagation, pruning, pests and diseases, trees, shrubs and shrubberries, climbers and creepers, palms, grass and lawns, ferneries and pot plants, rockeries, water gardens and marshy ground annual flower garden, lily bulbs and tubers, roses, chrysanthemums, cannas and orchids. The fifth part of the book deals with vegetables and fruits in a very brief and elementary form. In most of the cases

just a para and in some cases a few lines are devoted. In a comprehensive book like this more attention should have been paid to the fruit and vegetable section like the ornamental horticulture, as these form the basis of Indian horticulture. The last part deals with recipes of some popular preservatives for using home grown fruits and vegetables, birds and the garden, garden implements and in the end, a garden calendar showing different garden operations to be performed in each calendar month, is included. (S.S.)

AT FREEDOM'S DOOR

EDITED BY MALCOLM DARLING

(*Published by Oxford University Press, London, 369, Rs. 14*)

THIS book will be a landmark in the literature dealing with the economic and political problems of Indian's checqured history, at one of its most critical and romantic periods. For fact is stranger than fiction, in this that, without a single shot being fired, the Great Britainic Empire in India, passed into the annals of romance and history, handing over authority and sovereignty to the peoples' representatives. Freedom, for which the people, whom the author met in his knightly passage, from one end of India to the other, yearned, was thus gained in manner unique in the world's record. Strangely enough, and more than the author himself would recognize it will be an estimate of what this Great Empire did for the peasant folk on the hand, and what the new Government could achieve in the couple of years in which it held responsibility. The book, therefore, will be of high value from both points of view.

Mr. Malcolm Darling is a name to conjure with in the Punjab (undivided) and even in the rest of India, wherever authentic appraisement is needed of the rural situation and the economic circumstances of the village peoples. There are few men living, foreign or Indian, who could equal and none who could surpass, the knowledge and understanding he possesses of this sector of India's economy. So this enquiry of his, on horseback, a style not new to him must command the attention of all students of the Indian Rural Problem. It was characteristic of Mahatma Gandhi when he met him to greet him with the remark : 'So you have been riding 1,400 miles, but walking is best.' It is doubtful if the author would have profitted more in the attainment of information that he was seeking, though being on foot he undoubtedly would have come closer to the folk nearest to the soil. His having officials with him, while helpful, would have distorted the picture he obtained, but for the insight and knowledge he himself possessed of his subject. There is enough record to indicate that the discussions he had in various villages he stayed in or passed through, went to the realities of the situation, without any reservations. The presence of his gifted daughter in his journeys was of special significance, because she could contribute to his knowledge and impressions only what a woman's eyes and ears could discern in the subtle situation existing in rustic India. Arthur Young when he undertook his famous ride in 1789, across france, did not enjoy this advantage ! Not only in the directly economic sphere

but also in the far more vital functions of rural society, the role of women in India is immense. This may sound strange in the ears of foreigners, but this is the real situation. The story as related by the author is witness to this truth. It is good to know that Pandit Jawahar Lal Nehru became deeply interested in the author's plan to ride across India on horseback to see things for himself, a way of travel which would have been dear to his own heart! He took time over the plans and himself wrote to people of his own United Provinces to give all assistance to the explorers in their study tour.

We obtain a very real picture of rural India, its thoughts and its needs, its deficiencies and drawbacks, its aspirations and hopes. To an Indian it is matter for much gratification that throughout the tour, the party met with no discourtesy, except possibly the lack of thought on the part of those occupying the Circuit House mentioned on page 266. But then those were not country-folk! Unlike the mountains, our plains are not particularly striking for their scenic beauty. Yet for those who have eyes to see, there is much of attraction even from the landscape point of view. The author every now and then mentions scenery, vistas, panorama and views that prove that the country is not so flat and dull after all. His surprise is that the country-folk did not appreciate the marvels of the sunset or the charm of the countryside! This is indeed true. But peasants all over, with the exception possibly of Japan, are the same all over the world.

One supreme point must be recorded and that was the loving care the author, his daughter and son-in-law, devoted to their mute but important companions, namely their horses. To this must also be added the care and consideration they always showed for their servants. Both these traits of the British have left an indelible impression upon the public that came close to them during their rule and sojourn in India.

The three important questions the author was primarily interested in, were matters of economics, politics and administrative change. In the political sphere it is clear that while the people desired freedom, each with their own interpretation placed upon it, there was present, as the author abundantly proves, intensely bitter hostility between the Muslim and the Non-Muslim. This, also, exhibited itself in diabolic ferocity unprecedented in the dark history of human crime and mass insanity! Few there would be who would care to dwell upon this passage of our history, and so we pass on.

The author's impressions about the quality of the Administration make dismal reading. But the truth of it cannot be denied. The most significant observation, coming from an able and distinguished Administrator himself, will carry due weight, was the loss of the personal touch that he noted and deplored the most. While the peoples' representatives are there, and various types of democratic institutions have been set up, as for instance the Village Panchayats or Councils, yet in rural India, at any rate, there is still abundant scope and need for the personal touch of the District Officers and others. The authorities themselves are hardly to blame. Most of them would themselves deplore the lack of opportunity to get into touch with the people. Change in the mode of transportation in itself has been a potent

cause in producing the gap between the Administrators and the ruled. And, more than that, the vast increase of multitudinous duties heaped upon the overworked officials, leaves them no leisure to meet the people in their homes and still less time to think out problems for their intrinsic good. This is what the learned Author observes '. . . . Till then the administration had been a monarchy tempered by bureaucracy --the monarchy of the district officer by the bureaucracy of the Secretariat. But as Departments multiplied and Secretariats grew, it gradually turned into a bureaucracy tempered, ever less and less, by monarchy. Throughout the tour one had the feeling of an administration in only the loosest touch with the people and served by officials, many of whom, but not all, paid far more attention to the demands of Government than to the needs of the people.' This is an observation that must cause much disquietitude. It is clear that in the interim period, till such time as our village representative institutions again gather force, experience and prestige, the District Officers and his cohort of officials, must retain and extend the personal touch with the governed.

As for the lack of public amenities, like roads, schools, hospitals, dispensaries, sanitary neglect of the villages and the like, surely the newly installed Indian Government could not be expected to achieve and accomplish what the British Government in their long rule could not provide with any degree of adequacy. All that may be said is that many schemes, in fact far too many, have been promised in all these directions. Quite a few have been actually put into execution. There can be hardly any doubt that given internal tranquillity, and international peace, the present Government will have no reason to be downcast for what they will have carried through in the next ten years.

The author has laid his finger upon one of the weakest links of the administrative chain of Government. He observes: 'A long felt difficulty in improving village conditions is the poor quality of much of the personnel employed for the purpose. Too many of those we met—there were fine examples to the contrary—had little real feeling for the peasant or interest in doing more for him than an all too flexible sense of duty obliged.' He is also correct in what he writes of the new Departments of Civil Supplies, Rationing and the like. Their performance have made them notorious even above the doings of the Police and the Public Works Department. Bribery, corruption and nepotism are some of the worst maladies from which the country is at present suffering. Due to high prices, scarcity of commodities, abundant purchasing power in the hands of those who possess least of civic sense, and unprecedented power and authority in the grasp of those who are ill-used to it, have caused this deterioration. However, it is abundantly clear that the public will not endure such handling with patience for long. Government too, both at the Centre and in the States, are fully appraised of the situation. It is to be hoped that things will be righted before long; otherwise if India should tread the path that China has gone, it would not occasion surprise.

The author has regarded six factors as playing an important role in changing the face of things in the rural areas. He says, ' There are six factors which make

for change in the Indian village—education, a period of prosperity or adversity, the services supplied by Government, the army, the motor bus, and the neighbourhood of a large town'. Other vital forces could also be indicated : the emancipation urge of women, assertion of the lower castes, political consciousness and other influences that are making the rural situation in India manifestly dynamic. The author writes, ' Touch, water and temple are the crucial barriers, and the first to give way is touch.' As regards the Brahmin, he observes, 'Though many will touch his feet, massage his legs and give him first call on their meagre supply of milk, he is no longer treated as a demi-god'. Another significant change noticed by the author is mentioned as the trend of things. 'On the other hand, the village had built itself a school rather than a temple.' A vast problem so potent for the country, and no less basic to the slender resources of the peasant himself, is summed up in this talk of a peasant, "When a bullock has worked ten years for me, am I to sell it because it can work no longer ? I am not so entirely without pity as that'. 'Around this doctrine of *ahinsa* which has its roots embedded in the Buddhistic tradition worked into the Hindu system of religious observances, have grown up certain tenacious rural usuages. The author writes, 'The peasant lives too near the jungle not to make certain exceptions—in one village there were snakes, mad dogs and poisonous lizards, but when the threat is to crops and not to life, he holds his hand, and India's inadequate food supply suffers accordingly'. 'But here too change is discernible.....Great, therefore, was my surprise to find that in village of Hindu jats, fifty to sixty of them (monkeys) had been shot. This was the most daring innovation we came across, and it would, I think have had the approval of Mahatma Gandhi, who 20 years ago said it might be necessary to do this if the growing of fruit and vegetables required it (*Young India*, October 1938). Recent calculations have computed the monkey population of the country to be in the neighbourhood of about 50 millions, consuming and partly destroying food grains amounting upto four million tons, the shortage which the country has to meet with imports from abroad, at heavy cost ! Apart from the raising of more fruit and vegetable crops, the author noticed that poultry-farming was taking on especially amongst *ex*-army men. He also observed two new habits, wide-spread, namely that of tea-drinking and smoking of the leaf cigarette, instead of the traditional *hooka*. In touching upon another aspect in striking contrast to what one reads by most writers, it is refreshing to read : 'Here I fill I must enter a protest against the charge of squalor and slum frequently levelled at the Indian village, a charge far more applicable to town and townlet. In a country of 650,000 villages it would be strange if there were not many which were ill kept, but if I may judge by what I have seen in different parts of India, there are many, perhaps even more, which have nothing very serious to be ashamed of. The photographs facing page 211 will perhaps give some idea of the charm of many of those we saw in Madhya Pradesh and have been equally charming ones in Eastern Bengal, while I doubt whether even a Dutch interior could exceed in shining cleanliness the *Jangli* dwellings of the Western Punjab.' The author rightly points out that what is needed is more space for human habitation than is now allotted for *abadi* purposes in our villages, such is the pressure of the population for food requirements, that land

cannot be spared from cultivation needs. Land-hunger is so great that one peasant informed the author 'If there were land in Mars, we would go there!'

The author has not fought shy of touching upon the crucial question of population growth, that so many of our politicians and even economists, try to pass over. He found that the people in the villages are alive to the question, some more keenly than others, but all are up against it as it were. The women have begun to feel it and well they might! Change, therefore will not be long in coming, if the Administration can help. Family loyalties are rapidly shifting, and the docile Hindu wife is not so meek and mild as she may look. If mothers-in-law are consulted no doubt upon the subject would be left!

Altogether this book is a deeply fascinating study. It reads like a romance. It treats of a vast territory, inhabited by one of the most arresting of peoples that have a history that is lot in the dim beginnings of human civilization, at a juncture when they enter from one epoch into another. It could only have been written by a great scholar-administrator, certain of knowledge, deep of sympathy, powerful of vision. To him our debt is great. (S.K.R.)

COTTAGE INDUSTRIES AND AGRICULTURE IN JAPAN

By Chaman Lal

(*Published by New Book Company, Ltd., Hornby Road, Bombay, 249, Rs. 15*)

An extremely readable and interesting book, which should be read not only by those interested in Indian agriculture but also by those who are champions of the rapid industrialization of the country.

The author, who has travelled eight times round the world, writes with considerable experience of men and things. He maintains that if Japan, with a density of population greatest in the world, has developed a vast industrial empire, India with greater facilities and availability of raw materials can do the same. With an impressive array of facts and statistics, Mr. Chaman Lal refutes the theory that no industry can flourish if the raw materials are not locally available. He lists the cotton, tin, rubber and steel industries of Japan, the raw materials of which are imported.

Japan's 120 rural industries form the foundation of the country's phenomenal industrial expansion. Its small industries are concentrated to the extent of 54 per cent in one-man workshops and 40 per cent in small plants employing less than five workers. Among the factors which have helped Japan to outstrip advanced nations in producing cheap goods on a mass scale, are the country's mild climate, which makes sustained labour possible, the mass literacy of the workers, their high sense of responsibility and innate love of their country, efficient organization and careful planning of the export campaign, the concentration of industries in villages where raw materials are locally available, the electrification of home industries, the availability of fully trained technicians in every industry and industrial education for cottage industries.

The author devotes a whole chapter to the women of Japan, whom he describes as the very soul of Japan's home industries. Their hard and efficient work would however, have been of little use but for the well-organized plan of the Japanese Government to take machines and electric power into every home.

The book is replete with interesting details of the Japanese gift of making the most use of available materials. Next to Buddhism, the bamboo was India's most valuable gift to Japan. Today Japan grows more than 100 varieties of bamboo and 1,400 articles are made from it and 300 from paper!

The chapter on agriculture in Japan contains much useful material for India battling against food shortages. Only 16 per cent of that island's area is cultivated from which it secures 80-85 per cent of its food requirements. Japan produces three times more rice per acre than India and she holds the highest record of milk production. The main secret of high production in Japan, particularly of rice, is the use of better varieties and commercial fertilizers. Japan maintains 225 agricultural research stations for food crops like rice, wheat and barley.

The suggestions made for increasing agricultural production in India are valuable not for anything that has not been said before, but for their emphasis on problems which have been receiving the importance due to them, in recent times.

A very useful and readable book. (A.R.V.)

THE FARMER SPEAKS

By I. W. Moomaw

(*Published by the Oxford University Press, Bombay, 199, Rs. 7-8*)

IT is a valuable description of the rural economy of Gujerat prior to the last war.

Dr Moomaw has used the very helpful technique of recording in successive chapters a number of actual conversations with farmers, thus presenting their problems not in an abstract manner but as actual problems of particular people. This naturally leads to a certain amount of overlapping, which again itself has the value of pointing out how interrelated all of the problems of village life are, and the necessity of understanding the total life of village people if one is to help constructively in improving any aspect of village life.

Those who look at the tables included in the book with a hope to finding out an indication of the present finanical status of the cultivators, will be disappointed. The chief reason for this is that the data for the book were gathered about twelve years ago long before the enormous social and political changes that have precipitated during the last few years and the inflationary spiral that has characterized the economy of the last decade. Thus, the financial statements made in the book serve better as a history of what was true in Gujerat twelve years ago rather than as a description of the present economic conditions.

The value of the book for present use has both in reminding us of the conditions prevalent a few years ago as well in setting us to think about the implications of the changes which have come about in the past few years.

Dr Moomaw writes from the background of his long experience as the Principal of the Vocational Training School, Ankleswar, and the considerable first-hand knowledge of Gujerati agricultural conditions that he possesses.

Every college library should have this book on its shelf-available for students, teachers and research workers in agricultural economics. (A.T.M.)

THE LIVING SOIL

By E. B. Balfour

[*Published by Faber and Faber Ltd., 24 Russell Square, London, Revised (Nineth) Edition 1949, Price: 15s.*]

THE author has very ably discussed the controversy with regard to the general superiority of crops produced by the use of organic manures as compared to artificial fertilizers. It is pointed out that the claims of the humus school are based on numerous observations and while that may not claim the finality of scientific evidence there is enough reason to prove that organic manures provide a necessary symbiotic relationship between the inert soil and the living plant, resulting in conditions under which crop growth and yield are marked by 'quality' rather than 'quantity'. This makes for the ability of the crop to resist disease and other unfavourable conditions. It is claimed that the produce of such crops when used for animal and human consumption is nutritionally complete, in contrast to crops grown on fertilizers, to which may be attributed the increasing decline in health and vigour of the human population ever since fertilizers came to be extensively used in agriculture. The author makes a plea for regeneration of our race through complete food grown on organic manures only.

It must be conceded, however, that there is by now a volume of undoubted experimental evidence proving that the production capacity of soils can be improved and significant increases in yields obtained by the judicious use of fertilizers alone. It has also been possible to obtain normal crops raised on nutrient solutions only in soil-less culture. Organic manures by themselves have often failed to give similar responses in yield, indicating that they lack the balance in some of the essential nutrient elements required for plant growth. In this respect of course the contention of the humus school is that organic manures are by no means active store houses of stimulating nutrients for crop requirements like fertilizers. While chemical analysis has failed to prove so far any inferiority of crops raised on fertilizers in the known nutritional elements, there is some scientific evidence that crops raised on organic manures are less susceptible to attacks of pests and diseases and can stand other unfavourable conditions better. Viswanath showed that seed obtained from a crop manured with F. Y. M. exhibited growth factors which were lacking in seed obtained from fertilized area. Howard's observations on the resistence of organic

manured crops to attack of rust and other diseases and pests, provide enough evidence to explore the relationship of such manures to this capacity and to determine the factor or factors responsible for the observed superiority of such crops, and examine certain facts observed wherever organic manures have been exclusively used and determine whether or not there are factors which give to crops additional nutritive value, resistance to pests and diseases and general vigour as a result of organic manuring, which fertilizer manuring fails to give.

The fact that none of the so far known factors have been found to be in defect in fertilized crops indicates that the problem has to be tackled in a different manner from the existing methods. There is, therefore, need for (1) further observations in the long term experiments on the growth and behaviour of crops grown with organic manures and fertilizers, (2) nutritional experiments on the two types of crop produce and (3) detailed study of the effect of humus on soil, soil population and the relationship of this to plant nutrition.

The author has however certainly presented enough material for thought for workers interested in maintaining and improving soil fertility and human health. The growth and activities of the Haughley Research Trust and the Soil Association will interest not only the agricultural and nutritional scientists but all general public. As the author is herself the organizing Secretary of the Panel of Experts of the Soil Association, she has had ample opportunity to think over the matter and has put forward her view with conviction.

The get up of the book is excellent and it has been presented in an excellent manner. There are a number of the good illustrative plates. The book should find a place in the libraries of all Educational Institutions particularly those of Agricultural Science and in the book shelf of every worker on soil and plant and animal nutrition. (S.P.R.)

SHARING AND FIXED TENANCY SYSTEMS

By V. V. Sayana

(*Published by Business Week Press, Madras, 137, Rs. 3*)

IT is an interesting brochure on a subject which has not received so far the attention it deserves. An objective study of the great variations in rents with reasons for the same is urgently called for—for laying down our future policy regarding tenancy. The author has endeavoured to help in this matter though the subject is too vast for just a monograph and requires much more detailed data than could be presented here.

It is certainly interesting to know that rents in Madras State vary from Re. 1 per acre to Rs. 400. It is not uncommon it seems for rent in paddy growing areas to be as high as 10 bags where the gross yield is only 12 bags (1 bag=166 lb.) and rents such as these exclude certain head-loads of straw, etc., given to landlords. The author admits that the margin left to the tenant is 'unduly low', though it is rather difficult to understand why he believes that 'the total benefits' obtained by

the tenant 'amply compensate the expenses incurred....services rendered....and the capital invested ....and provide at least a minimum living.' This statement is extremely puzzling unless of course minimum living' is meant to include semi-starvation. This is important as the author admits on another page that several tenants are working actually at a loss. Whilst we are at this point, it is also worth recording that a critical reader would like to know on what basis the author has worked out his figures of net income of owner cultivators and tenants as given on page 95, etc., of the book. Such figures can be totally misleading unless it is shown how expenses of cultivation were calculated, whether they included all legitimate items like value of the labour of the cultivator or his family, etc.

Dr. Sayana has done well to draw pointed attention to the prevalence of 'extras and other exactions' and in feeling happy at the step taken by the Bombay Government in passing the Tenancy Act of 1948. But whilst the Bombay Government can be congratulated on prohibiting levy of such cesses and services of all kinds by landlords, the same thing can not be said of the Government of Madras. The absence of such legislation is a black spot on the record there. A legislature that is unable to act in time is the best ally, without knowing it, of its own enemy—communism.

The author seems to be sure that farm-leasing must and will decline in the future but one cannot help feeling that it is not easy to be very enthusiastic about owner-farming as we see it in different parts of the world. To expect riches and prosperity from owner-farming is to hug illusions. It is certainly as dangerous to associate prosperity with owner-farming as it is to associate poverty always with tenant-farming. Here is a subject where conclusions should be less emphatic, the data presented more ample and the remedies prescribed more thorough going. In England, for example, where owner-farming has failed and tenant cultivation, the rule, the remedies prescribed even by conservative thinkers are not ordinary make-shift panaceas but a thorough going nationalisation of land. Here is a subject again where indeed the farm manager will have plenty of scope to differ from the theoretical agricultural economist. (P.N.D.)

AGRARIAN PROBLEMS OF MADRAS STATE

By V. V. Sayana

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THIS book is largely a thesis for the Ph. D. degree but as the author tells us it is supposed to cater for 'four types of readers—the student of economics the public, research worker, and the expert'. 'One feels however that too much has been attempted to cater for too many and the result is not too happy.'

There are 11 chapters in all, some of which one may suppose are meant only for the student or the public whose knowledge of economics is not too wide. These chapters will be disappointing to the last two types of readers.

Chapter V deals with *zamindari* in Madras. One feels that the author would have done well to read all the available books on the subject. It may be however that he has not acknowledged his debt to certain sources as freely as is required. Chapter VI deals with Land Transfers and contains good material.

The succeeding chapter on Rural Credit, however, again becomes too elementary though it will serve the needs of the student and the public. The author seems to talk of 'structural defects' in co-operation as if they refer to co-operatives only in certain areas (page 184). This is a capital mistake and shows confusion of thought. Chapter VIII and X deal with problems of tenancy and may be taken as constituting again good material. Tenancy problems are, however, also the subject of his other book as reviewed above, in details. Of the two remaining chapters one deals with Labour and the other with Agrarian Reforms.

In dealing with the constructive side the author avoids 'Radicalism', a phrase which he defines as 'the method of going into the origin and striking at the very fundamental root causes of any problem'. The author's method is even 'to retrace a step backward in order to march three steps forward'. This may not be acceptable to all, particularly since it is clear that a step backward when we are already on the edge of a precipice is not a healthy step forward.

There is no doubt that the author has tried to compromise on as many issues as possible on the constructive side. But this surely is not the best way even if it pleases the maximum number of people. There is already a lot of confused thinking on the vital problem of land tenure. It cannot be said that the author has lessened this confusion. To give one minor example, in his Ph. D. thesis the author has 'recommended that Crop-sharing system may be prohibited in all its forms and fixed rents ....may be paid'. In his second book on 'Sharing and Fixed Tenancy System' however he has recommended that the above passage should be read as implying that 'the crop sharing system may be allowed to continue side by side with the system of fixed rents'. As against this second change he has come to a third conclusion on page 118 of his small monograph that 'there is nothing fundamentally wrong with the form of share-tenancy which if properly amended would prove probably more advantageous'. (P.N.D.)

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